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MANUFACTURING METHOD OF GEOGRID

FIELD OF THE INVENTION

The present invention relates to a method for manufacturing geogrids. More specifically, the present invention relates to an improved method for manufacturing woven geogrids, which can be used with foundations, soils, rock, earth, or other geomechanical materials to provide selective separation and reinforcement. The method disclosed in the present invention has many distinct advantages in that (1) it can be readily and easily implemented on-site; (2) it reduces manufacturing costs and minimizes or eliminates waste disposal problems that can cause environmentally pollution concerns; and (3) the geogrids so manufactured exhibit superior qualities.

BACKGROUND OF THE INVENTION

Geogrids have been used in various civil engineering and mining applications such as soil stabilization, reinforcement, and other applications. Geogrids can be provided in soft or hard forms.. Typically, the soft geogrids comprise intersecting (typically via weaving process) strands made from high tensile strength filaments so as to provide high load support characteristics. The grid openings formed from the intersecting stands typically are rectangular or square in shape, with the strands being placed at an angle of about 90 ° relative to each other. However, other shapes and/or relative angles may be used. Depending on the size of the grid, composition of the strands, and other factors, the commercially available geogrids may also be called geocells, geonets, or geocomposits. One of the companies that market these products is Tenax Company, located in Baltimore, Maryland.

The most common process in making geogrids involves the five main steps of (1) spinning high-strength filament yarns; (2) warping; (3) weaving to form a two-dimensional net structure; (4) coating with polyvinylchloride (PVC) or asphalt; and (5) drying/solidification to form the final geogrid. The purpose of the step of coating with PVC or asphalt is to cause the high-strength filament yarns to form filament bundles that are aggregated and covered by this matrix of binder

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material, which also serves as a protective material. The step of prepregging with PVC or asphalt also imparts many desired properties, such as UV-resistance and acid/base-resistances, to the grid structures.

It was observed by the co-inventors of the present invention that the geogrids made from the conventional process have several drawbacks. The most notable inadequacy with the conventional geogrids is that, because the only the fiber bundles (i.e., the so-called "ribs" of the geogrid) and the intersections thereof (i.e., the "nodal points") of the geogrids are covered by the PVC binder material, and no binder material is provided between the individual fibers, their junction strength is very poor. This severely limits the types of engineering projects that geogrids can be utilized with confidence. Furthermore, because the fiber bundles are prepregged with PVC or asphalt, the conventional process has raised serious environmental pollution concerns and causes clean-up problems.

In U.S. Pat. No. 5,091,247, it is disclosed a process for making woven geotextile grid (i.e., geogrid) for earth reinforcement applications. The grid is formed of woven fabric which is coated with a suitable polyvinylchloride or other plastic coating. The fabric is formed of a plurality of spaced-apart pick (i.e., transversal) yarn bundles which are interwoven with a plurality of spaced-apart warp (i.e., longitudinal) yarn bundles. The pick yarn bundles are held in place in the warp yarn bundles with locking yarns which run parallel to the pick yarns and which are positioned adjacent to the edges of the pick yarn bundles. The warp yarns extend between the pick yarn bundles and locking yarns to lock the pick yarn bundles into place. A plurality of pairs of leno yarns oriented parallel to the warp yarns additional strengthen the fabric by interlocking with one another in the spaces between the pick yarn bundles and locking yarns. After the fabric leaves the loom, it is dipped in a heated polyvinylchloride bath and dried using heating elements before being rolled for storage or shipment. The process disclosed in the '247 patent basically follows the convention process by dipping the woven fabric into a PVC bath, followed by drying/heating to form the geotextile grid. Again, because the PVC coating is only applied to the bundle surface and there is no adhesion force between the individual fibers, its junction strength is poor.

In U.S. Pat. No. 5,045,377, it is disclosed a process for making continuous fiber reinforced composite grid. The grid structures are formed by joining continuous fiber reinforced/resin matrix compound composite strands with similar compound composite strands, or with simple unreinforced plastic strands. The compound composite reinforced strands are formed by using prepreg, which comprises reinforcing fibers embedded in a plastic resin matrix. The prepreg tapes are fed from a supply roll into a die, and are continuously pulled through the die. In a separate route, a thermoplastic resin is supplied into the die and deposited onto the tapes to provide encapsulation of the prepreg in a second layer of plastic. Thereafter, thermoplastic resin is allowed to flow out to form transverse strands, thus resulting in a web or grid structure. The process discloses in the '377 patent differs from most of the conventional processes in that, among other things, first, it utilizes glass-fiber reinforced composites, thus its cost is substantially higher. Second, since the transverse direction strands are deposited onto the machine direction strands, the geogrids so produced are not woven geogrids; rather, they are non-woven geogrids. The geogrids produced from the '377 process provided several advantages while also suffer disadvantages. However, the '377 process still utilizes the same basic approach as the conventional process in that the thermoplastic resin is heated and melted to thereby provide a coating on the surface of the composite fiber.

In U.S. Pat. No. 5,199,825, it is disclosed a process for making a grid composite for protecting men and longwell mining equipment during longwell shield recovery. In this invention, a polymer grid is connected to a grid composite consisting of a polymer grid and a geotextile. The grid composite is formed by use of a polymer grid which is heat bonded to a continuous filament polyester, non-woven needle-punched engineering fabric. The engineering fabric or geotextile is bonded to the polymer grid using an open flame heat source or using a heated roll as a heat source. During the process, plastic pellets are melted and compressed by an extruder, and a gear pump and a melt mixer are used to provide a homogeneous melt. Since the process discloses in the '825 patent involves the step of bonding a polyester geotextile to a biaxial grid material formed by needle-punching, the geogrids so produced do not solve the lack of junction strength problem encountered in the conventional geogrids.

As discussed above, the conventional geogrids have a major limitation in that, because there is no binder material between the individual fibers within each fiber bundle, they lack the desired junction strength. While sever inventions have be disclosed to improve the properties of geogrids, they have not solved this problem. Therefore, it is desirable to develop an improved process so as to overcome this problem and enhance the applicability of geogrids. It is also equally desirable to develop an improved process which would make the manufacturing of geogrids environmentally compatible.

SUMMARY OF THE INVENTION

The primary object of the present invention is to develop an improved process for making woven geogrids. More specifically, the primary object of the present invention is develop an improved method for manufacturing geogrids, which can be used with foundations, soils, rock, earth, or other geomechanical materials to provide selective separation and reinforcement. The method disclosed in the present invention provides many distinct advantages in that: (1) the process can be readily and easily implemented on-site; (2) it reduces manufacturing costs and is highly environmentally compatible; and (3) the geogrids so manufactured exhibit superior qualities, including excellent mechanical strength and low rate of elongation.

One of the main advantages of the process disclosed in the present invention is that it does not require the equipment and steps for receiving, containing and melting a thermoplastic (or asphalt) feed, and coating (i.e., dipping) the molten thermoplastic onto a geotextile fabric, as required by the prior art processes. Because the prior art processes involve the handling of a very hot (typically above 150 °C) molten polymer or asphalt mass, they require relatively expensive equipment and often result in a highly hazardous work environment. Furthermore, the unused thermoplastic resin or asphalt can cause serious disposal problems and often are environmental headaches.

Another distinct advantage of the process disclosed in the present invention is that, while all

of the prior art processes can only achieve the purpose of applying a binder composition covering the yarn bundles and leaving the individual fibers uncovered, the present invention allows the coating composition to effectively penetrate into and intimately cover the individual fibers in an ubiquitous manner. The ubiquity of the coating composition down to the individual fiber level allows the geogrids made from the process disclosed in the present invention to exhibit superior qualities over those made from the prior art processes, especially with regard to the junction strength. Thus the present invention not only allows a superior product to be made, it also allows the product to be made in an economically more cost-effective, procedurally more adaptive, and environmentally more conscientious manner.

In the process disclosed in the present invention to form a geogrid, one or more high-melting point filament yarns and one or more low-melting point filament yarns are first combined into a hybrid bundle. After warp beaming, the hybrid bundle is woven or twisted into a net structure with a predetermined grid pattern. The grid pattern can be a rectangular or square shape with a predetermined grid opening. The net structure is then passed through a heat treatment causing the low-melting point filament yarn to melt and thereby ubiquitously bind the individual high-melting point fibers. After cooling, a soft geogrid with excellent mechanical and chemical properties is produced. The grid structure can be made in a plant off-site or at the construction site.

The hybrid bundles disclosed in the present invention comprises at least one high-melting point filament yarn and at least one low-melting point filament yarn. The high-melting point and low-melting point filament yarns can be provided separately, or they can be provided as bi-component fibers with the required dual composition differentiated by melting points. The high-melting point filament yarn should possess the qualities of high strength, high modules and low strain rate, so as to provide the function as a reinforcement material for the woven geogrid. Examples of the high-melting point filament yarns that can be used in the present invention include polyesters, such as poly(diethyl *p*-phthalate), poly(dibutyl *p*-phthalate), etc; polyamides, such as nylon 6, nylon 66, etc; and glass and carbon fibers. On the other hand, the main function of the low-melting point filament yarn is to serve as a matrix or binder, and its strength is of relatively secondary consideration.

Examples of the low-melting point filament yarns that can be used in the present invention include polyethylene, polypropylene, co-polyesters, polyamides such as nylon, etc. It is preferred that low-melting point filament yarns are selected such that the melting point of the high-melting point filament yarns is at least 20°C greater than that of the low-melting point filament yarns. The low-melting point filament yarns can be selected from the same class of polymers that can be used as the high-melting point filament yarns, the main point is they must have a lower melting point.

It is preferred that the hybrid yarn bundle contains the high-melting point filament yarns and the low-melting point filament yarns in a weight ratio of 50 ~ 70% to 30 ~ 50%. These two types of filament yarns are spun then subjected to warp beaming; optionally, they can be subject to additional steps before warp-beaming. Thereafter, the fiber bundles can be subjected to the weaving operation. Because the yarns formed in the present invention belong to the type of filament yarns, they can be used in various types of weaving machines, such as warp knitting or warp twisting machines, to form the desired grid structures. Typically, the grid dimension can be 20 x 20 or 20 x 30 mm, etc. After the weaving process, the woven product can be placed in an oven, or other heat treatment devices, and heated at temperatures preferably about 10 ~ 20 °C above the melting point of the low-melting point filament yarns, to thereby form the final geogrid product.

By using the hybrid bundle, the present invention does not require the costly and messy prepregging step which has always been required in the prior art processes. By doing so, the process disclosed in the present invention eliminates the need for the coating facility, its also reduces the size of the processing plant as well as the cost of other related equipment. But more importantly, the process disclosed in the present invention greatly reduces the processing time and minimizes potential environmental pollution problems. Furthermore, with the process disclosed in the present invention, the high-strength fibers (i.e., the high-melting point fibers) are intimately contacted by the binder or matrix resin (formed from the low-melting point fibers), excellent adhesion is provided between the individual fibers and at the intersections of the fibers. This results in greatly improved junction strength and overall strength of the geogrids so produced.

BRIEF DESCRIPTION OF THE DRAWING

The present invention will be described in detail with reference to the drawing showing the preferred embodiment of the present invention, wherein:

Fig. 1 is a schematic drawing showing the steps of forming a polymeric geogrid according to the most common prior art processes.

Fig. 2 is a schematic drawing showing the steps of form a polymeric geogrid according to a preferred embodiment of the present invention.

Fig. 3 is a microscopic photograph showing the arrangement of the polyester fibers made from the conventional process, at 100 X.

Fig. 4 is a microscopic photograph showing the arrangement of the polyester fibers made from a preferred embodiment of the present invention, at 100 X.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention discloses an improved process for making polymeric geogrids, which can be used with foundations, soils, rock, earth, or other geomechanical materials to provide selective separation and reinforcement. The method disclosed in the present invention provides many distinct advantages. First, the process can be readily and easily implemented on-site without requiring excessive extra equipment. Second, it reduces the manufacturing time and cost and is highly environmentally compatible. Third, the geogrids manufactured from the process disclosed in the present invention exhibit superior qualities, including high junction strength, low elongation, and high overall strength.

As described above, the process disclosed in the present invention does not require the equipment and steps for receiving, containing and melting a thermoplastic (or asphalt) feed, nor does it requires the equipment and steps for coating the molten thermoplastic onto a geotextile fabric. Both of these elements are required by the prior art processes, which involve the handling of a very hot (typically above 150 °C) molten polymer or asphalt mass. As a result, the prior art processes often require relatively expensive equipment and often result in a highly hazardous work environment. Furthermore, the unused thermoplastic resin or asphalt mass can cause serious disposal problems and often present environmental headaches.

The process disclosed in the present invention also allows the binder composition to effectively penetrate into and intimately cover the individual fibers. This is a distinct advantage over all of the prior art processes, in which the binder composition only covers the fiber bundles and leaves the individual fibers uncovered. The ubiquity of the coating composition down to the individual fiber level allows the geogrids made from the process disclosed in the present invention to exhibit superior qualities over those made from the prior art processes, especially with regard to the junction strength. The present invention thus not only allows a superior geogrid to be made, it also enables the product to be made in a more cost-effective and environmentally-conscientious manner.

In the process disclosed in the present invention, at least one high-melting point fiber and at least one low-melting point fiber are first spun to form a hybrid fiber bundle (or yarn). After warp beaming, the hybrid bundle is woven or twisted into a net structure with a predetermined grid opening, which can be a rectangular or square shape with a predetermined grid dimension. The woven net structure containing the hybrid yarns is then heated causing the low-melting point fiber to melt and thereby form a matrix binding the high-melting point fibers. After cooling, a soft geogrid with excellent mechanical and chemical properties is provided. The grid structure can be made from a manufacturing plant or at the construction site.

The hybrid bundle disclosed in the present invention preferably comprises a plurality of high-melting point filament yarns and a plurality of low-melting point filament yarns, and both types of

filament yarns should be of long lengths. It is preferred that the hybrid yarn bundles contain the high-melting point filament yarns and the low-melting point filament yarns in a ratio of 50 ~ 70% to 30 ~ 50%, by weight of the fibers. The high-melting point and low-melting point filament yarns can be provided as separate yarns, or they can be provided as bi-component yarns with the similarly requisite dual compositions. If bi-component filament yarns are used, they can be either sheath-and-core type or side-by-side type. The high-melting point fiber, which provides the function as a reinforcement material for the polymeric geogrid, should possess the desired qualities of high strength, high modules and low strain rate. Preferred examples of the high-melting point fibers that can be used in the present invention include polyesters, such as poly(diethyl *p*-phthalate), poly(dibutyl *p*-phthalate), etc; and polyamides, such as nylon 6, nylon 66, etc. Glass fibers and carbon fibers may also be used as the reinforcement fiber. The main function of the low-melting point fiber is to serve as a matrix or binder to contain the reinforcement fibers, and its strength is of secondary consideration. Preferred examples of the low-melting point fibers that can be used in the present invention include polyethylene, polypropylene, polyester copolymers, polyamides such as nylon, etc. It is preferred that low-melting point fibers are selected such that the melting point of the high-melting point fibers is at least 20°C greater than that of the low-melting point fibers.

The high- and low-melting filament yarns are spun then subjected to warp beaming; optionally, they can be subject to other processing steps before warp beaming. Thereafter, the yarn bundles can be subjected to the weaving operation. Because the yarns formed in the present invention belong to the type of filament yarns, they can be used in various types of weaving machines, such as warp weaving or warp twisting machines, to form the desired grid structures. Preferably, the grid dimensions are 20 x 20 or 20 x 30 mm. Other dimensions can be easily implemented. After the weaving process, the woven product is placed in an oven and heated at temperatures preferably about 10 ~ 20 °C above the melting point of the low-melting point fibers, to thereby form the final geogrid product.

A distinct feature of the process disclosed in the present invention is that the present invention does not require the costly and messy coating step which has always been required in the prior art

processes. Rather, the present invention uses the hybrid yarn bundles comprising low- and high-melting filament yarns in the weaving process. This novel approach allows the process disclosed in the present invention to eliminate the need for the coating equipment, its also reduces the plant size and the cost for other equipment. As a result, the process disclosed in the present invention was able to greatly reduce the processing time and minimize potential environmental pollution problems. In addition to the cost savings, the geogrids produced from the process disclosed in the present invention also exhibit unexpectedly superior qualities. With the process disclosed in the present invention, the reinforcement fibers are intimately contacted and enclosed by the binder or matrix resin, excellent bonding is provided between the individual fibers and at the intersections of these fibers. This resulted in greatly improved junction strength as well as excellent overall strength.

Now refer to the drawings. Fig. 1 is a schematic drawing showing the steps of forming a polymeric geogrid according to the most common prior art processes. High strength filament fibers 2 are provided from the roll support 1 and spun to form yarns 3. The yarns are processed through a warp beam 4 and are woven in a weaver 5 to form a woven net structure consisting of grid ribs and nodes formed of fiber bundles. The net structure is then passed through a dipping bath 6, and a pair of compression-suction rollers 7. The dipping bath 6 contains a coating composition, typically polyethylene, to apply a layer of protective and binder composition covering the fiber bundles. Finally the coated woven net structure is heated and dried in an oven 8 and taken up by a take-up roller 9 to form a geogrid.

Fig. 2 shows a schematic drawing showing the steps of forming a polymeric geogrid according to a preferred embodiment of the present invention. High-melting point filament yarns 12 and low-melting point filament yarns 13 are simultaneously provided from the roll support, or creel, 11 and are combined to form yarn bundles (or cheese) 14. The yarn bundles are processed through a warp beam 15 and woven in a leno weave machine 16 to form a woven net structure consisting of grid ribs and nodes formed of yarn bundles. Alternately, a warp knitting machine can be used in place of the leno weave machine 16. Instead of passing through the dipping bath as shown in Fig. 1 of the prior art processes, the woven net structure is sent directly to the oven 17, where the woven net structure

is heated and dried, and then is cooled and taken up by a take-up roller 18 to form a geogrid. The elimination of the dipping bath greatly simplifies the manufacturing process, reduces the manufacturing cost (in both the capital cost and operation cost), improves the manufacturing condition, and ameliorates environmental pollution concerns.

Fig. 3 is a microscopic photograph showing the arrangement of the polyester fibers in a geogrid made from the conventional process. And Fig. 4 is another microscopic photograph showing the arrangement of the polyester fibers in another geogrid made from a preferred embodiment of the present invention. Fig. 3 shows that the fibers are arranged as a collection of fiber aggregates, with each fiber aggregate being the bundle of fibers that had been spun together during the spinning process, and no binder is provided for the fibers within each aggregate. On comparison, Fig. 4 shows a uniform distribution of the individual fibers, and the entire population of the fibers are engrossed by the matrix of low-melting point resins. This distinct difference in the morphology relating to the arrangement of individual fibers enables the geogrid of the present invention to exhibit excellent properties over those of the prior art.

The present invention will now be described more specifically with reference to the following example. It is to be noted that the following descriptions of examples, including the preferred embodiment of this invention, are presented herein for purposes of illustration and description, and are not intended to be exhaustive or to limit the invention to the precise form disclosed.

Example 1

In this example, the high-melting point fibers were a high-strength poly(diethyl *p*-phthalate) fibers (polyester) with a yarn denier of 1,000 d/190 fibers, and the low-melting point fibers were a polyethylene fibers with a yarn denier of 192 d/32 fibers. Sixteen of the high-strength poly(diethyl *p*-phthalate) fibers were combined with thirty-two of the polyethylene fibers to form a yarn. After

warp beaming, the yarns were woven into a net structure having a grid opening of 20 x 20 mm. The woven net structure was heated at a temperature of 150 °C for 4 min so as to cause the low-melting point fibers to melt and bind the high-strength poly(diethyl *p*-phthalate) fibers. After cooling, the net structured solidified to form the geogrid ready for use.

The foregoing description of the preferred embodiments of this invention has been presented for purposes of illustration and description. Obvious modifications or variations are possible in light of the above teaching. The embodiments were chosen and described to provide the best illustration of the principles of this invention and its practical application to thereby enable those skilled in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the present invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.

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WHAT IS CLAIMED IS:

1. A method for manufacturing geogrids comprising the steps of:
   (a) combining at least one high-melting point fiber in the form of a filament yarn with at least one low-melting point fiber also in the form of a filament yarn to form a hybrid fiber bundle, wherein said low-melting point fiber has a melting point that is at least 10 °C lower than the melting point of said high-melting point fiber;
   (b) weaving said hybrid fiber bundle to form a net structure;
   © heating said net structure causing said low-melting point fiber to bond and form a binder composition enclosing said high-melting point fiber; and
   (d) cooling said net structure to form a geogrid.

2. A method for manufacturing geogrids according to claim 1 wherein the melting point of said low-melting point fiber is at least 20 °C lower than the melting point of said high-melting point filament fiber.

3. A method for manufacturing geogrids according to claim 1 wherein said hybrid fiber bundle comprises a plurality of said high-melting point filament yarns and a plurality of said low-melting point filament yarns.

4. A method for manufacturing geogrids according to claim 1 wherein said high-melting point fiber is selected from the group consisting of poly(diethyl *p*-phthalate), poly(dibutyl *p*-phthalate), polyamides, glass fibers, and carbon fibers.

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5. A method for manufacturing geogrids according to claim 4 wherein said polyamide is nylon 6 or nylon 66.

6. A method for manufacturing geogrids according to claim 1 wherein said low-melting point fiber is selected from the group consisting of polyethylene, polypropylene, polyester copolymers, and polyamides.

7. A method for manufacturing geogrids according to claim 6 wherein said polyamide is nylon 6 or nylon 66.

8. A method for manufacturing geogrids according to claim 1 wherein said hybrid fiber bundle is formed by combining said high-melting point fiber and said low-melting point fiber together.

9. A method for manufacturing geogrids according to claim 1 wherein said hybrid fiber bundle is a bi-component fiber formed by compositing said high-melting point fiber and said low-melting point fiber to form a bi-component fiber.

10. A method for manufacturing geogrids according to claim 9 wherein said bi-component fiber is a sheath-and-core type or side-by-side type fiber.

11. A method for manufacturing geogrids according to claim 1 wherein said hybrid fiber bundle comprises about 50 to 70 percent by weight of said high-melting point fiber and about 30 to

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50 percent by weight of said low-melting point fiber.

12. A method for manufacturing geogrids according to claim 1 wherein said high-melting point fiber has a melting point above 150 °C.

13. A method for manufacturing geogrids comprising the steps of:

(a) combining at least one first fiber in the form of a filament yarn with at least one second fiber also in the form of a filament yarn to form a hybrid fiber bundle, wherein said first fiber has a melting point above 150 °C and said second fiber has a melting point that is at least 10 °C lower than the melting point of said first fiber;

(b) weaving said hybrid fiber bundle to form a net structure;

© heating said net structure at a temperature which causes said second fiber to melt and form a binder composition enclosing said first fiber; and

(d) cooling said net structure to form a geogrid.

14. A method for manufacturing geogrids according to claim 13 wherein the melting point of said second fiber is at least 20 °C lower than the melting point of said first fiber.

15. A method for manufacturing geogrids according to claim 13 wherein said hybrid fiber bundle comprises a plurality of said first yarn filaments and a plurality of said second fiber yarn filaments .

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16 A method for manufacturing geogrids according to claim 13 wherein said hybrid fiber bundle comprises about 50 to 70 percent by weight of said first fiber and about 30 to 50 percent by weight of said second fiber.

17. A polymeric geogrid comprising a plurality of intersecting longitudinal and transversal fiber bundles, each of said fiber bundles comprising a plurality of first fibers dispersed in a continuous matrix of a polymeric binder resin in a spaced-apart manner with said polymeric binder resin filling therebetween, said polymeric geogrid being made from a process comprising the steps of:

(a) combining a plurality of said first fibers with a plurality of second fibers made from said polymeric binder to form a hybrid fiber bundle, wherein said first fiber has a melting point that is at least 10 °C greater than the melting point of said second fiber;

(b) weaving said hybrid fiber bundle to form a net structure;

© heating said net structure at a temperature which causes said second fiber to melt and form a binder composition enclosing said first fiber; and

(d) cooling said net structure to form a geogrid.

18. A geogrid according to claim 17 wherein said first fiber is selected from the group consisting of poly(diethyl *p*-phthalate), poly(dibutyl *p*-phthalate), polyamides, glass fibers, and carbon fibers.

19. A geogrid according to claim 17 wherein said first fiber wherein said second fiber is selected from the group consisting of polyethylene, polypropylene, polyester copolymers, and polyamides.

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