Civil infrastructure, such as roads, continues to age and underperform and there is a growing need to replace and upgrade these assets. Concurrently, the materials traditionally used in construction of roads and other civil infrastructure continue to increase in cost and scarcity, particularly due to the environmental impacts of quarrying for high quality natural aggregates. As a result, there is a growing need for use of materials that are more readily available and that have lower environmental impacts in sourcing. Typically, these materials differ in their properties from traditional materials, and often have lower performance capabilities.

Therefore, a commercial and environmental need exists for a geogrid material that can facilitate improved performance and economies while at the same time lessen the environmental impact of civil infrastructure such as roads. A need therefore exists for an integral geogrid having a geometry that can engage with, confine and stabilize a greater variety and range of quality of aggregates than geometries associated with conventional geogrids, and having a geometry that includes continuous strands in at least two directions, while simultaneously providing a variety of degrees of localized out-of-plane stiffness, in addition to other desirable properties not available with current integral geogrids.

SUMMARY

In an aspect, the present disclosure refers to a multi-axial integral geogrid comprising:

a plurality of interconnected oriented strands and partially oriented junctions forming a repeating pattern of outer hexagons having an array of openings therein,

supporting ribs extending inwardly from each of said outer hexagons to support inside each of said outer hexagons a smaller inner hexagon having an unobstructed, open center and oriented strands and tri-nodes, each of said tri-nodes interconnecting only one of said supporting ribs and two of said oriented strands of the inner hexagon,

said outer hexagons, said supporting ribs and said inner hexagons defining three different geometric configurations which are repeating throughout an entirety of the geogrid, and

said oriented strands and said partially oriented junctions of said outer hexagons defining a plurality of linear strands that extend continuously throughout an entirety of the geogrid.

In an aspect, the present disclosure refers to a starting material for making a multi-axial integral geogrid comprising a polymer sheet having a pattern of holes or depressions therein that provide three different shaped openings, including an outer hexagon and a smaller inner hexagon having an unobstructed, open center and oriented strands and tri-nodes, and a plurality of linear strands that extend continuously throughout an entirety of the geogrid without intersecting an inside of the outer hexagon, when the sheet is biaxially stretched.

In an aspect, the present disclosure refers to a method of making a multi-axial integral geogrid, comprising:

providing a polymer sheet;

providing a patterned plurality of holes or depressions in the polymer sheet; and

orienting the polymer sheet having the patterned plurality of holes or depressions therein to provide a plurality of interconnected oriented strands and partially oriented junctions forming a repeating pattern of outer hexagons having an array of openings therein, supporting ribs extending inwardly from each of said outer hexagons to support inside each of said outer hexagons a smaller inner hexagon having an unobstructed, open center and oriented strands and tri-nodes, each of said tri-nodes interconnecting only one of said supporting

ribs and two of said oriented strands of the inner hexagon, said outer hexagons, said supporting ribs and said inner hexagons defining three different geometric configurations which are repeating throughout an entirety of the geogrid, and said oriented strands and said partially oriented junctions of said outer hexagons forming a plurality of linear strands that extend continuously throughout an entirety of the multi-axial integral geogrid.

In an aspect, the present disclosure refers to a method of making a multi-axial integral geogrid, comprising:

providing a polymer sheet;

providing a patterned plurality of holes or depressions in the polymer sheet; an orienting the polymer sheet having the patterned plurality of holes or depressions therein to provide a plurality of interconnected oriented strands and partially oriented junctions forming a repeating pattern of outer hexagons having an array of openings therein, supporting ribs extending inwardly from each of said outer hexagons to support inside each of said outer hexagons a smaller inner hexagon having an unobstructed, open center and oriented strands and tri-nodes, each of said tri-nodes interconnecting only one of said supporting ribs and two of said oriented strands of the inner hexagon so as to enable the inner hexagon to float up and down relative to a plane of the associated outer hexagon, said outer hexagons, said supporting ribs and said inner hexagons defining three different geometric configurations which are repeating throughout an entirety of the geogrid, and said oriented strands and said partially oriented junctions of said outer hexagons defining a plurality of linear strands that extend continuously throughout an entirety of the multi-axial integral geogrid.

In an aspect, the present disclosure refers to a method of providing a multi-axial integral geogrid construction, comprising:

biaxially stretching a starting material that is a polymer sheet having a patterned plurality of holes or depressions therein to provide a multi-axial integral geogrid having a plurality of interconnected oriented strands and partially oriented junctions forming a repeating pattern of outer hexagons

having an array of openings therein, supporting ribs extending inwardly from each of said outer hexagons to support inside each of said outer hexagons a smaller inner hexagon having an unobstructed, open center and oriented strands and tri-nodes, each of said tri-nodes interconnecting only one of said supporting ribs and two of said oriented strands of the inner hexagon, said outer hexagons, said supporting ribs and said inner hexagons defining three different geometric configurations which are repeating throughout an entirety of the geogrid, and said oriented strands and said partially oriented junctions of said outer hexagons defining a plurality of linear strands that extend continuously throughout an entirety of the multi-axial integral geogrid; and

embedding the multi-axial integral geogrid in a mass of particulate material.

In an aspect, the present disclosure refers to a multi-axial integral geogrid comprising:

a plurality of interconnecting oriented strands and partially oriented junctions forming a repeating pattern of a selected outer geometric shape having an array of openings therein;

each of said outer geometric shapes supporting and surrounding a smaller inner geometric shape having an unobstructed, open center and oriented strands, which inner geometric shape is the same as or different from the outer geometric shape;

said oriented strands and said partially oriented junctions of said outer geometric shape forming at least two sets of substantially parallel linear strands that extend continuously throughout the entirety of the geogrid, and

said geogrid having a thickness of from about 3 mm to about 9 mm.

In an aspect, the present disclosure refers to a reinforced and stabilized composite soil structure comprising:

a mass of particulate material; and

a multi-axial integral geogrid embedded in and engaging with said particulate material and having a plurality of interconnected oriented strands and partially

oriented junctions forming a repeating pattern of outer hexagons having an array of openings therein,

supporting ribs extending inwardly from each of said outer hexagons to support inside each of said outer hexagons a smaller inner hexagon having an unobstructed, open center and oriented strands and tri-nodes, each of said tri-nodes interconnecting only one of said supporting ribs and two of said oriented strands of the inner hexagon,

said outer hexagons, said supporting ribs and said inner hexagons defining three different geometric configurations which are repeating throughout an entirety of the geogrid, and

said oriented strands and said partially oriented junctions of said outer hexagons forming a plurality of linear strands that extend continuously throughout an entirety of the multi-axial integral geogrid.

In an aspect, the present disclosure refers to a multi-axial integral geogrid comprising:

a plurality of interconnected oriented strands and partially oriented junctions forming a repeating pattern of outer hexagons having an array of openings therein,

supporting ribs extending inwardly from each of said outer hexagons to support inside each of said outer hexagons a smaller inner hexagon having an unobstructed, open center and oriented strands and tri-nodes, each of said tri-nodes interconnecting only one of said supporting ribs and two of said oriented strands of the inner hexagon,

said oriented strands, said partially oriented junctions, said supporting ribs, and said inner hexagons forming at least three different geometric configurations which are repeating throughout an entirety of the geogrid, and

said oriented strands and said partially oriented junctions of said outer hexagon defining a plurality of linear strands that extend continuously throughout the entirety of the geogrid.

In an example, the present disclosure refers to a method of determining the performance of a particular geogrid in connection with a particular aggregate which comprises:

conducting a standardized retention test with said geogrid and a quantity of said aggregate, and

determining whether the geogrid captures at least about 50% of said aggregate during said test.

To attain the aforementioned geometry that can engage with, confine and stabilize a greater variety and range of quality of aggregates than geometries associated with prior geogrid structures, and having a geometry that includes continuous strands in at least two directions, while simultaneously providing a variety of degrees of localized out-of-plane and in-plane stiffness, and other desirable characteristics, the present invention provides a monolayer multi-axial grid having a repeating geometry comprising different shapes and sizes of apertures, formed from ribs of different lengths, heights and widths, in which the ribs preferably have an aspect ratio greater than 1.0, and in which