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(71) Applicant: **WASHINGTON STATE UNIVERSITY**
[US/US]; Lighty 280/286, PO Box 641060, Pullman, Wash-
ington 99164-1060 (US).

(72) Inventors: **YADAMA, Vikram**; c/o Washington State Uni-
versity, Lighty 280/286, PO Box 641060, Pullman, Wash-
ington 99164-1060 (US). **CHANDA, Avishek**; c/o Wash-
ington State University, Lighty 280/286, PO Box 641060,
Pullman, Washington 99164-1060 (US).

(74) Agent: **ALMEIDA, Francisco J.** et al.; Klarquist Spark-
man, LLP, One World Trade Center, 121 SW Salmon St.,
Suite 1600, Portland, Oregon 97204 (US).

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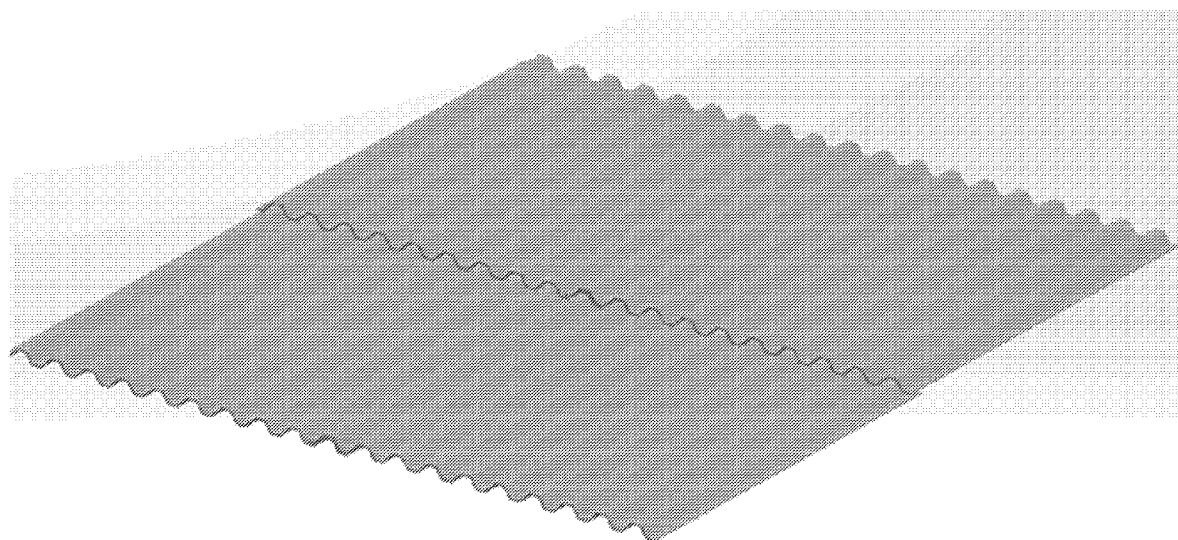


FIG. 15A

(57) Abstract: Disclosed herein are aspects of a corrugated non-woven bamboo composite panel comprising a pitch, depth, rib span, and rib radii within parameters that increase the load bearing capacities. Also disclosed herein is a method of making and using the corrugated non-woven bamboo composite panel disclosed herein. In certain aspects, the non-woven bamboo composite panels disclosed herein have a suitable stacking ability for shipping and form desirable gaps between the panels during roof assembly.



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**BAMBOO-BASED STRAND COMPOSITE PANELS FOR CONSTRUCTION
APPLICATIONS**

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of the earlier filing date of U.S. Provisional Application No. 63/654,788, filed May 31, 2024, and U.S. Provisional Application No. 63/595,705, filed November 2, 2023, each of which is incorporated by reference in its entirety herein.

FIELD

[0002] The present disclosure concerns a corrugated non-woven bamboo composite panel and methods of making and using the corrugated non-woven bamboo composite panel.

ACKNOWLEDGMENT OF GOVERNMENT SUPPORT

[0003] This invention was made with government support under Grant No. 2136481, awarded by the National Science Foundation. The government has certain rights in the invention.

BACKGROUND

[0004] The world-wide population is ever increasing, and the resources required to not only shelter people (*e.g.*, roofing materials), but also the roofing construction materials needed in the construction of schools, hospitals, etc. are also increasing in both demand and cost. Bamboo is an eco-friendly roofing alternative due to its abundance. However, roofing designs that incorporate bamboo have many limitations such as reduced stiffness, one dimensional use, and higher moisture absorption. Additionally, conventional roofing designs that use bamboo are labor intensive and expensive, have slow production speeds, and require higher amounts of resin. Accordingly, there is a need in the art for 3-D corrugated bamboo roofing panel geometry having a high flexural modulus for load bearing capacities and downstream fabrication.

SUMMARY

[0005] Aspects of a corrugated non-woven bamboo composite panel are disclosed herein. In some aspects, the corrugated non-woven bamboo composite panel comprises a thickness ranging from 1 millimeter to 10 millimeters; a plurality of top rib spans and bottom rib spans forming a plurality of slopes comprising a rib radius ranging from 5 millimeters to 15 millimeters; a corrugation depth

ranging from 5 millimeters to 50 millimeters measured from a lower portion of the lower rib spans to a lower portion of the top rib spans; and a pitch ranging from 50 millimeters to 200 millimeters measured from a center portion of the top rib spans.

[0006] A corrugated construction panel is also disclosed herein, the corrugated composite panel comprising: a bamboo-based material; a plurality of top rib spans forming a plurality of upward slopes and a plurality of bottom rib spans forming a plurality of downward slopes having a slope angle ranging from 40 degrees to 60 degrees; a thickness ranging from 3 millimeters to 7 millimeters; and a load bearing capacity ranging from 3 N/mm to 5 N/mm.

[0007] Also disclosed herein is a roofing assembly, comprising: a first construction panel, wherein the first construction panel is the corrugated construction panel disclosed herein; and a second construction panel onto the first construction panel, wherein the second construction panel is the corrugated construction panel disclosed herein.

[0008] A method of making the making a corrugated panel is also disclosed herein, the method comprising: introducing a bamboo-based material; mixing the bamboo-based material with an adhesive; providing the mixture into a mold comprising a geometry for producing the bamboo-based construction panel disclosed herein; and pressing the mixture at a temperature ranging from 280°F to 400°F and under a pressure ranging from 2 MPa to 7 MPa.

[0009] Also disclosed herein is a method comprising introducing a container having a height ranging from 1015 millimeters to 2035 millimeters; and providing 100 or more of the bamboo-based construction panel disclosed herein into the container, wherein the 100 or more bamboo-based construction panels are stacked.

[0010] The foregoing and other objects, features, and advantages of the present disclosure will become more apparent from the following detailed description, which proceeds with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1A is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 120 millimeters, a depth of 35 millimeters, and a slope angle of 51.29°.

[0012] FIG. 1B is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 120 millimeters, a depth of 22 millimeters, and a slope angle of 51.29°.

[0013] FIG. 1C is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 150 millimeters, a depth of 35 millimeters, and a slope angle of 51.29°.

[0014] FIG. 1D is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 150 millimeters, a depth of 30 millimeters, and a slope angle of 45°.

[0015] FIG. 1E is a schematic drawing showing aspects of the two-dimensional profile of the bamboo-based composites disclosed herein comprising a pitch of 147.99 millimeters, a depth (d) of 30 millimeters, and a slope angle of 45°.

[0016] FIG. 2A is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 80 millimeters, a depth of 20 millimeters, a slope angle of 38.66°, and a flattened length of 1430.89 millimeters.

[0017] FIG. 2B is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 120 millimeters, a depth of 20 millimeters, a slope angle of 29.74°, and a flattened length of 1324.19 millimeters.

[0018] FIG. 2C is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 160 millimeters, a depth of 20 millimeters, a slope angle of 23.96°, and a flattened length of 1280.16 millimeters.

[0019] FIG. 2D is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 80 millimeters, a depth of 27 millimeters, a slope angle of 60.95°, and a flattened length of 1701.8 millimeters.

[0020] FIG. 2E is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 120 millimeters, a depth of 27 millimeters, a slope angle of 47.2°, and a flattened length of 1452.88 millimeters.

[0021] FIG. 2F is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 160 millimeters, a depth of 27 millimeters, a slope angle of 22.56°, and a flattened length of 1298.79 millimeters.

[0022] FIG. 2G is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 80 millimeters, a depth of 35 millimeters, a slope angle of 81.87° , and a flattened length of 2147.15 millimeters.

[0023] FIG. 2H is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 120 millimeters, a depth of 35 millimeters, a slope angle of 37.87° , and a flattened length of 1459.65 millimeters.

[0024] FIG. 2I is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 160 millimeters, a depth of 35 millimeters, a slope angle of 32.47° , and a flattened length of 1369.91 millimeters.

[0025] FIG. 3A is an illustration showing the E_1 axis, E_2 axis, and E_3 axis of the panel in its plan view.

[0026] FIG. 3B is a linear force versus displacement graph showing the results with respect to the displacement.

[0027] FIG. 4 is a schematic drawing showing a conventional corrugated profile of a comparator, Indian Standard (IS) 15476, demonstrating decreased stiffness, one dimensional use, minimal bond area, and increased resin content.

[0028] FIG. 5 is a schematic drawing showing aspects of the bamboo-based composites disclosed herein demonstrating a rib radius, depth and pitch for achieving a profile with increased bending stiffness and suitable geometry that is desirable and transferable to the industry.

[0029] FIG. 6A is a graph showing the signal-to-noise (S/N) ratios calculated for the bending stiffness for different aspects of the depth of the bamboo-based composites disclosed herein.

[0030] FIG. 6B is a graph showing the signal-to-noise (S/N) ratios calculated for the bending stiffness for different aspects of the pitch of the bamboo-based composites disclosed herein.

[0031] FIG. 6C is a graph showing the signal-to-noise (S/N) ratios calculated for the bending stiffness for different aspects of the span of the bamboo-based composites disclosed herein.

[0032] FIG. 6D is a graph showing the signal-to-noise (S/N) ratios calculated for the bending stiffness for different aspects of the rib radius of the bamboo-based composites disclosed herein.

[0033] FIG. 6E is a bar graph showing the Pareto-ANOVA results on bending stiffness for depth, pitch, rib span, and rib radius of a bamboo-based composite disclosed herein.

[0034] FIG. 7 is a schematic drawing showing a sandwich structure used for calculating the interlaminar shear strength.

[0035] FIG. 8A is a schematic drawing showing aspects of the two-dimensional profile of the bamboo-based composites disclosed herein.

[0036] FIG. 8B is a schematic drawing showing aspects of the two-dimensional profile of the bamboo-based composites disclosed herein.

[0037] FIG. 9A is a schematic drawing showing aspects of the two-dimensional profile of the bamboo-based composites disclosed herein.

[0038] FIG. 9B is a schematic drawing showing aspects of the three-dimensional profile of the bamboo-based composites disclosed herein.

[0039] FIG. 10A is an image showing aspects of the bamboo-based composites disclosed herein comprising a plurality of transverse ribs.

[0040] FIG. 10B is a bar graph showing the bond area comparison for a mold having a rib radius of 13.5 millimeters, a mold without transverse ribs, a mold with transverse ribs, and a mold having a rib radius of 10 millimeters.

[0041] FIG. 11 is a schematic drawing showing the dimensions of the comparator, Indian Standard (IS) 15476.

[0042] FIG. 12A is bar graph showing the bending stiffness for the comparator (IS); a bamboo-based composite disclosed herein comprising a pitch of 120 millimeters, a depth of 35 millimeters, and a slope angle of 51.29° ; a bamboo-based composites disclosed herein comprising a pitch of 120 millimeters, a depth of 22 millimeters, and a slope angle of 51.29° ; a bamboo-based composites disclosed herein comprising a pitch of 150 millimeters, a depth of 30 millimeters, and a slope angle of 45° ; and a bamboo-based composites disclosed herein comprising a pitch of 150 millimeters, a depth of 35 millimeters, and a slope angle of 51.29° .

[0043] FIG. 12B is bar graph showing the interfacial shear stress for the comparator (IS); a bamboo-based composite disclosed herein comprising a pitch of 120 millimeters, a depth of 35 millimeters, and a slope angle of 51.29°; a bamboo-based composites disclosed herein comprising a pitch of 120 millimeters, a depth of 22 millimeters, and a slope angle of 51.29°; a bamboo-based composites disclosed herein comprising a pitch of 150 millimeters, a depth of 30 millimeters, and a slope angle of 45°; and a bamboo-based composites disclosed herein comprising a pitch of 150 millimeters, a depth of 35 millimeters, and a slope angle of 51.29°.

[0044] FIG. 13 is a schematic drawing showing aspects of a three-dimensional profile of a mold for producing a bamboo-based composite disclosed herein.

[0045] FIG. 14 is a schematic drawing showing a plurality of bamboo-based composite disclosed herein demonstrating the desirable stacking ability.

[0046] FIG. 15A is a schematic drawing showing a roofing assembly comprising the bamboo-based composite disclosed herein.

[0047] FIG. 15B is a schematic drawing showing the single overlap gap and double of the comparator (IS).

[0048] FIG. 15C is a schematic drawing showing the single overlap gap and double overlap gap of the bamboo-based composite disclosed herein.

[0049] FIG. 16 is a schematic drawing showing aspects of a three-dimensional profile of a mold for producing a bamboo-based composite disclosed herein.

DETAILED DESCRIPTION

I. Overview of Terms

[0050] The following explanations of terms are provided to better describe the present disclosure and to guide those of ordinary skill in the art in the practice of the present disclosure. As used herein, “comprising” means “including” and the singular forms “a” or “an” or “the” include plural references unless the context clearly dictates otherwise. The term “or” refers to a single element of

stated alternative elements or a combination of two or more elements unless the context clearly indicates otherwise.

[0051] The methods described herein should not be construed as limiting in any way. Instead, the present disclosure is directed toward all novel and non-obvious features and aspects of the present disclosure, alone and in various combinations and sub-combinations with one another. The disclosed methods are not limited to any specific aspect or feature or combinations thereof, nor do the disclosed methods require that any one or more specific advantages be present, or problems be solved. Any theories of operation are to facilitate explanation, but the methods are not limited to such theories of operation.

[0052] Although the operations of some of the disclosed methods are described in a particular, sequential order for convenient presentation, it should be understood that this manner of description encompasses rearrangement, unless a particular ordering is required by specific language set forth below. For example, operations described sequentially may in some cases be rearranged or performed concurrently. Moreover, for the sake of simplicity, the attached figures may not show all the various ways in which the disclosed devices and methods can be used in conjunction with other devices and methods. Additionally, the description sometimes uses terms like “produce” and “provide” to describe the disclosed methods. These terms are high-level abstractions of the actual operations that are performed. The actual operations that correspond to these terms will vary depending on the particular implementation and are readily discernible by one of ordinary skill in the art. Furthermore, examples may be described with reference to directions indicated as “above,” “below,” “upper,” “lower,” and the like. These terms are used for convenient description, but do not imply any particular spatial orientation unless so indicated.

[0053] In some examples, values, procedures, or devices may be referred to as “lowest,” “best,” “minimum,” or the like. It will be appreciated that such descriptions are intended to indicate that a selection among many used functional alternatives can be made, and such selections need not be better, smaller, or otherwise preferable to other selections.

[0054] Unless explained otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this disclosure belongs. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present disclosure, suitable methods and materials are described below. The materials, methods, and examples are illustrative only and not intended to be

limiting, unless otherwise indicated. Other features of the disclosure are apparent from the following detailed description and the claims.

[0055] Unless otherwise indicated, all numbers expressing quantities of components, molecular weights, percentages, temperatures, times, and so forth, as used in the specification or claims are to be understood as being modified by the term “about.” Accordingly, unless otherwise indicated, implicitly or explicitly, the numerical parameters set forth are approximations that can depend on the desired properties sought and/or limits of detection under standard test conditions/methods. When directly and explicitly distinguishing embodiments from discussed prior art, the embodiment numbers are not approximations unless the word “about” is recited. Furthermore, not all alternatives recited herein are equivalents.

II. Introduction

[0056] A conventional bamboo roofing design used is by cutting open bamboo in half, the nodes within the bamboo culm are removed and cut into adequate sizes, and the resulting bamboo halves are placed in an interlocking manner such that one half faces the ground and the other facing the sky. Another structure is a corrugated design, wherein bamboo is provided in sheets configured as a plurality of woven bamboo mats. These mats are then treated with an adhesive resin. A hydraulic press binds the sheets together and gives the sheets an “S” shape. Another design includes thin slices of bamboo woven together in a crossing pattern made to cover a roof. The Indian standard (IS 15476) on Bamboo Mat Corrugated Sheets, used herein as a comparative example, outlines a geometry for corrugated bamboo roofing. However, such a geometry has many limitations, including reduced stiffness, one dimensional use, and higher moisture absorption. It is also labor intensive, slower production speeds, expensive and requires undesirably high amounts of resin.

[0057] Disclosed herein are bamboo-based composites comprising reduced moisture absorption and desirable geometric parameters designed around depth, pitch, rib span, rib angle, and rib radius that results in a suitable flexural modulus for load bearing capacities and downstream fabrication of sandwich panels with single or multiple 3-D core layers. Also disclosed herein is a mold for producing aspects of the corrugated non-woven bamboo construction panels disclosed herein. Also disclosed herein are aspects of a method of making and using the corrugated non-woven bamboo construction panels disclosed herein.

[0058] In some aspects, the bamboo-based composites can include bamboo strand panel geometry in a suitable load carrying system while maintaining a desirable 3-dimensional (3D) profile. In certain aspects, the bamboo-based composites comprise a pitch, depth, rib span, and rib radii having suitable parameters for producing a desirable flexural modulus for load bearing capacities. In aspects disclosed herein, the corrugated non-woven bamboo construction panels comprise a stackable geometry that allows for a greater number of panels to be stacked for post-production transportation from the manufacturing site and therefore decreases shipping costs. In certain aspects, a roofing assembly comprising the corrugated non-woven bamboo construction panels that form gaps for increasing ventilation in housing units.

III. Composite Panels

[0059] Disclosed herein are aspects of a non-woven bamboo composite panel comprising a wall having a plurality of upward slopes resulting in a plurality of top rib spans and a plurality of downward slopes resulting in a plurality of lower rib spans, wherein the slopes are arranged with a rib radius. In certain aspects, the non-woven bamboo composite panel comprises a depth that measured from a first portion of the wall such as, but not limited to, a bottom portion of the lower rib spans) to a second portion of the wall such as, but not limited to, the bottom portion of the top rib spans. In particular aspects, the non-woven bamboo composite panel comprises a pitch, which is the distance between a center portion of a top rib span to the center portion of the next top rib span.

[0060] In aspects disclosed herein, the non-woven bamboo composite panel comprises a thickness ranging from 1 millimeter to 10 millimeters; a plurality of top rib spans and bottom rib spans forming a plurality of slopes comprising a rib radius ranging from 5 millimeters to 15 millimeters; a depth ranging from 5 millimeters to 50 millimeters measured from a lower portion of the lower rib spans to a lower portion of the top rib spans; and a pitch ranging from 50 millimeters to 200 millimeters measured from a center portion of the top rib spans.

[0061] In certain aspects, the corrugated non-woven bamboo composite panel can have a rib radius ranging from 8 millimeters to 15 millimeters such as from 8 millimeters to 14 millimeters, 8 millimeters to 13 millimeters, 8 millimeters to 12 millimeters, 8 millimeters to 11 millimeters, 8 millimeters to 10 millimeters, or 8 millimeters to 9 millimeters.

[0062] In some aspects, the corrugated non-woven bamboo composite panel can have a depth ranging from 6 millimeters to 35 millimeters, such as from 8 millimeters to 30 millimeters, 10 millimeters to 30 millimeters, 12 millimeters to 30 millimeters, 14 millimeters to 30 millimeters, 16 millimeters to 30 millimeters, 18 millimeters to 30 millimeters, 20 millimeters to 30 millimeters, 22 millimeters to 30 millimeters, 24 millimeters to 30 millimeters, 26 millimeters to 30 millimeters, or 28 millimeters to 30 millimeters.

[0063] In aspects disclosed herein, the corrugated non-woven bamboo composite panel can have a pitch ranging from 120 millimeters to 155 millimeters, such as from 125 millimeters to 155 millimeters, 130 millimeters to 155 millimeters, 135 millimeters to 155 millimeters, 140 millimeters to 155 millimeters, 145 millimeters to 155 millimeters, 146 millimeters to 155 millimeters, 147 millimeters to 155 millimeters, 148 millimeters to 155 millimeters, 149 millimeters to 155 millimeters, or 150 millimeters to 155 millimeters.

[0064] In certain aspects, the corrugated non-woven bamboo composite panels comprise top rib spans and bottom rib span having a length ranging from 5 millimeters to 150 millimeters, such as from 10 millimeters to 100 millimeters, 15 millimeters to 100 millimeters, 20 millimeters to 100 millimeters, 25 millimeters to 100 millimeters, 30 millimeters to 100 millimeters, 35 millimeters to 100 millimeters, 40 millimeters to 100 millimeters, 45 millimeters to 100 millimeters, 50 millimeters to 100 millimeters, 55 millimeters to 100 millimeters, 60 millimeters to 100 millimeters, 65 millimeters to 100 millimeters, 70 millimeters to 100 millimeters, 75 millimeters to 100 millimeters, 80 millimeters to 100 millimeters, 85 millimeters to 95 millimeters, or 90 millimeters to 95 millimeters.

[0065] In some aspects, the corrugated non-woven bamboo composite panel can have a plurality of slopes comprising one or more upward slopes and one or more downward slopes. In certain aspects, the one or more upward slopes and one or more downward slopes comprise a slope angle ranging from 40 degrees to 60 degrees. In certain aspects, the corrugated non-woven bamboo composite panels can have a slope angle ranging from 42 degrees to 55 degrees such from 44 degrees to 55 degrees, 46 degrees to 55 degrees, 48 degrees to 55 degrees, 50 degrees to 55 degrees, or 52 degrees to 55 degrees.

[0066] In aspects disclosed herein, the corrugated non-woven bamboo composite panel can have an overall flattened length ranging from 1400 millimeters to 1600 millimeters such from 1410 millimeters to 1600 millimeters, 1420 millimeters to 1600 millimeters, 1430 millimeters to 1600

millimeters, 1440 millimeters to 1600 millimeters, 1450 millimeters to 1600 millimeters, 1460 millimeters to 1600 millimeters, 1470 millimeters to 1600 millimeters, 1480 millimeters to 1600 millimeters, 1490 millimeters to 1600 millimeters, 1500 millimeters to 1600 millimeters, 1510 millimeters to 1600 millimeters, 1520 millimeters to 1600 millimeters, 1530 millimeters to 1600 millimeters, 1540 millimeters to 1600 millimeters, 1550 millimeters to 1600 millimeters, 1560 millimeters to 1600 millimeters, 1570 millimeters to 1600 millimeters, 1580 millimeters to 1600 millimeters, or 1590 millimeters to 1600 millimeters.

[0067] In some aspects, with reference to FIG. 1A, the corrugated non-woven bamboo composite panel comprises a thickness (t) of 6.35 millimeters, a rib span (s) of 29.6 millimeters, a rib radius (r) of 10 millimeters, a pitch (p) of 120 millimeters, a corrugation depth (d) of 35 millimeters, and a slope angle (a) of 51.29°.

[0068] In certain aspects, with reference to FIG. 1B, the corrugated non-woven bamboo composite panel comprises a thickness (t) of 6.35 millimeters, a rib radius (r) of 10 millimeters, a pitch (p) of 120 millimeters, a rib span (s) of 46.23 millimeters, a corrugation depth (d) of 22 millimeters, and a slope angle (a) of 51.29°.

[0069] In certain aspects, with reference FIG. 1C, the corrugated non-woven bamboo composite panel comprises a thickness (t) of 6.35 millimeters, a rib radius (r) of 10 millimeters, a pitch (p) of 150 millimeters, a corrugation depth (d) of 35 millimeters, a rib span (s) of 69.82 millimeters, and a slope angle (a) of 51.29°.

[0070] In some aspects, with reference to FIG. 1D, the corrugated non-woven bamboo composite panel comprises a thickness (t) of 6.35 millimeters, a pitch (p) of 150 millimeters, a corrugation depth (d) of 30 millimeters, and a slope angle (a) of 45°.

[0071] In certain aspects, with reference to FIG. 1E, the corrugated non-woven bamboo composite panel comprises a thickness (t) of 6.35 millimeters, a rib span (s) of 40 millimeters, a rib radius (r) of 8 millimeters, a pitch (p) of 147.99 millimeters, a corrugation depth (d) of 30 millimeters, and a slope angle (a) of 45°.

[0072] FIGS. 2A-2I are schematic drawings showing aspects of a three-dimensional profile of the corrugated non-woven bamboo composite panels disclosed herein comprising a pitch ranging between 80 millimeters to 160 millimeters, a depth ranging between 20 millimeters and 35 millimeters, a slope angle ranging between 23° and 82°, rib span ranging between 15 millimeters

and 35 millimeters, and a flattened length ranging between 1280 millimeters and 2150 millimeters. More specifically, as shown below in Table 1, FIG. 2A is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 80 millimeters, a depth of 20 millimeters, a slope angle of 38.66° , and a flattened length of 1430.89 millimeters. FIG. 2B is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 120 millimeters, a depth of 20 millimeters, a slope angle of 29.74° , and a flattened length of 1324.19 millimeters. FIG. 2C is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 160 millimeters, a depth of 20 millimeters, a slope angle of 23.96° , and a flattened length of 1280.16 millimeters. FIG. 2D is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 80 millimeters, a depth of 27 millimeters, a slope angle of 60.95° , and a flattened length of 1701.8 millimeters. FIG. 2E is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 120 millimeters, a depth of 27 millimeters, a slope angle of 47.2° , and a flattened length of 1452.88 millimeters. FIG. 2F is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 160 millimeters, a depth of 27 millimeters, a slope angle of 22.56° , and a flattened length of 1298.79 millimeters. FIG. 2G is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 80 millimeters, a depth of 35 millimeters, a slope angle of 81.87° , and a flattened length of 2147.15 millimeters. FIG. 2H is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 120 millimeters, a depth of 35 millimeters, a slope angle of 37.87° , and a flattened length of 1459.65 millimeters. FIG. 2I is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 160 millimeters, a depth of 35 millimeters, a slope angle of 32.47° , and a flattened length of 1369.91 millimeters.

FIG.	Depth (mm)	Pitch (mm)	Rib Span (mm)	Rib Radius (mm)	Flattened length (mm)
2A	20	80	15	10	1430.89
2B	20	120	25	13.5	1324.19
2C	20	160	35	17.25	1280.16
2D	27	80	25	17.25	1701.8
2E	27	120	35	10	1452.88
2F	27	160	15	13.5	1298.79
2G	35	80	35	13.5	2147.15
2H	35	120	15	17.25	1459.65
2I	35	160	25	10	1369.91

[0073] In certain aspects, the corrugated non-woven bamboo composite panel can have a thickness (t), rib span (s), rib radius (r), corrugation depth (d), and pitch (p) according to Equation 1A, and wherein the upper rib span spin has a thickness (t), rib span (s), rib radius (r), corrugation depth (d), and pitch (p) according to Equation 1B:

$$t_l = 0.109s_l = 0.475r_l = 0.633d_l = 0.03166p_l \text{ (Equation 1A)}$$

$$t_u = 0.069s_u = 0.64r_u = 0.183d_u = 0.04266p_u \text{ (Equation 1B)}$$

[0074] In some aspects, the corrugated non-woven bamboo composite can be a construction panel comprising suitable load bearing capacities. In certain aspects, the corrugated construction panel can have a load bearing capacity ranging from greater than 0 N/mm to 10 N/mm such as from 2 N/mm to 7 N/mm, or 3 N/mm to 5 N/mm.

[0075] In aspects disclosed herein, the corrugated panel comprises bamboo-based material. In certain aspects, the bamboo-based material can have a bending load ranging from 500 N-m to 1000 N-m, such as from 550 N-m to 950 N-m, or 600 N-m to 900 N-m.

[0076] In some aspects, the bamboo-based material is made from non-woven bamboo strips. In certain aspects, the bamboo-based material is made from non-woven bamboo strands. In particular aspects, the bamboo-based material is made from bamboo fibers. In some aspects, the bamboo-based material is made from bamboo particles. In aspects disclosed herein, the bamboo-based material is made from any combination of non-woven bamboo strips, non-woven bamboo strands, bamboo fibers, or bamboo particles.

IV. Methods

[0077] Also disclosed herein is a method of making the corrugated non-woven bamboo composite panel, the method comprising: introducing a bamboo-based material; mixing the bamboo-based material with an adhesive; providing the mixture into a mold comprising a geometry for producing the bamboo-based construction panel; and pressing the mixture at a temperature ranging from 200° F to 500 ° F, such as from 250 ° F to 450 ° F, or 280° F to 400° F and under a pressure ranging from 2 MPa to 7 MPa such as from 2.5 MPa to 5.5 MPa , or 2.75 MPa to 6.2 MPa.

[0078] In some aspects, the adhesive may comprise polymeric methylene diphenyl diisocyanate (pMDI), phenol formaldehyde (PF), melamine urea formaldehyde (MUF), or any combination thereof.

[0079] A method for assembling construction panels is also disclosed herein, the method comprising: providing a first construction panel, wherein the first construction panel is the corrugated construction panel disclosed herein; and placing a second construction panel onto the first construction panel, wherein the second construction panel is the corrugated construction panel disclosed herein.

[0080] In certain aspects, the method is for making a roofing assembly comprising the corrugated construction panels disclosed herein. In aspects disclosed herein, the first construction panel and second construction panel form a single overlap gap ranging from 1 millimeter to 10 millimeters; and a double overlap gap ranging from 5 millimeters to 20 millimeters. In certain aspects, the single overlap gap ranges from 2 millimeters to 5 millimeters such as from 2.5 to 4 millimeters, 3 millimeters to 4 millimeters, or 3.5 millimeters to 4 millimeters.

[0081] In some aspects, the method comprises stacking the bamboo-based construction panel disclosed herein. In certain aspects, the method comprises introducing a container having a height ranging from 20 inches to 100 inches; and providing the stacked bamboo-based construction panels disclosed herein into the container. In aspects disclosed herein, the container comprises a height ranging from 40 inches to 80 inches such as from 40 inches to 70 inches, 40 inches to 60 inches, or 40 inches to 50 inches. In some aspects, the container can be for transporting the bamboo-based construction panels such as, but not limited to, a pallet having a height of 48 inches. In aspects disclosed herein, 50 or more of the bamboo-based construction panel are provided into the container, 60 or more of the bamboo-based construction panel are provided into the container, 70 or

more of the bamboo-based construction panel are provided into the container, 80 or more of the bamboo-based construction panel are provided into the container, 90 or more of the bamboo-based construction panel are provided into the container, 100 or more of the bamboo-based construction panel are provided into the container, 102 or more of the bamboo-based construction panel are provided into the container, 104 or more of the bamboo-based construction panel are provided into the container, 106 or more of the bamboo-based construction panel are provided into the container, 108 or more of the bamboo-based construction panel are provided into the container, 110 or more of the bamboo-based construction panel are provided into the container, 112 or more of the bamboo-based construction panel are provided into the container, 114 or more of the bamboo-based construction panel are provided into the container, 116 or more of the bamboo-based construction panel are provided into the container, 118 or more of the bamboo-based construction panel are provided into the container, 120 or more of the bamboo-based construction panel are provided into the container, 122 or more of the bamboo-based construction panel are provided into the container, 124 or more of the bamboo-based construction panel are provided into the container, 126 or more of the bamboo-based construction panel are provided into the container, 128 or more of the bamboo-based construction panel are provided into the container, or 130 or more of the bamboo-based construction panel are provided into the container. In some aspects, the container can be for transporting the bamboo-based construction panels such as, but not limited to, a pallet having a height of 48 millimeters for post-fabrication shipping.

V. Overview of Several Aspects

[0082] Disclosed herein are aspects of a corrugated non-woven bamboo composite panel comprising: a thickness ranging from 1 millimeter to 10 millimeters; a plurality of top rib spans and bottom rib spans forming a plurality of slopes comprising a rib radius ranging from 5 millimeters to 15 millimeters; a corrugation depth ranging from 5 millimeters to 50 millimeters measured from a lower portion of the lower rib spans to a lower portion of the top rib spans; and a pitch ranging from 50 millimeters to 200 millimeters measured from a center portion of the top rib spans.

[0083] In any or all of the above aspects, the plurality of slopes comprise one or more upward slopes and one or more downward slopes, and wherein the one or more upward slopes and the one or more downward slopes have a slope angle ranging from 40 degrees to 60 degrees.

[0084] In any or all of the above aspects, the lower rib spin has a thickness (t), rib span (s), rib radius (r), corrugation depth (d), and pitch (p) according to Equation 1A, and wherein the upper rib

span spin has a thickness (t), rib span (s), rib radius (r), corrugation depth (d), and pitch (p) according to Equation 1B:

$$t_l = 0.109s_l = 0.475r_l = 0.633d_l = 0.03166p_l \text{ (Equation 1A)}$$

$$t_u = 0.069s_u = 0.64r_u = 0.183d_u = 0.04266p_u \text{ (Equation 1B)}.$$

[0085] In any or all of the above aspects, the rib radius ranges from 8 millimeters to 15 millimeters; the corrugation depth ranges from 6 millimeters to 35 millimeters; and the pitch ranges from 120 millimeters to 155 millimeters.

[0086] In any or all of the above aspects, the plurality of top rib spans and bottom rib spans have a length ranging from 25 millimeters to 95 millimeters.

[0087] In any or all of the above aspects, the plurality of top rib spans and the plurality of lower rib spans have a length ranging from 25 millimeters to 95 millimeters; the rib radius ranges from 5 millimeters to 10 millimeters; the corrugation depth ranges from 25 millimeters to 35 millimeters; and the pitch ranges from 145 millimeters to 155 millimeters.

[0088] In any or all of the above aspects, the composite panel comprises a flattened length ranging from 1400 millimeters to 1600 millimeters.

[0089] A corrugated construction panel is also disclosed herein, the corrugated composite panel comprising: a bamboo-based material; a plurality of top rib spans forming a plurality of upward slopes and a plurality of bottom rib spans forming a plurality of downward slopes having a slope angle ranging from 40 degrees to 60 degrees; a thickness ranging from 3 millimeters to 7 millimeters; and a load bearing capacity ranging from 3 N/mm to 5 N/mm.

[0090] In any or all of the above aspects, the plurality of top rib spans and bottom rib spans have a length ranging from 35 millimeters to 50 millimeters.

[0091] In any or all of the above aspects, the bamboo-based material has a bending load ranging from 600 N-m to 900 N-m.

[0092] In any or all of the above aspects, the plurality of upward and downward slopes comprise a rib radius ranging from 5 millimeters to 12 millimeters.

[0093] In any or all of the above aspects, the corrugated panel further comprises comprising a corrugation depth ranging from 30 millimeters to 40 millimeters; and a pitch ranging from 120 millimeters to 150 millimeters.

[0094] Also disclosed herein is a roofing assembly, comprising: a first construction panel, wherein the first construction panel is the corrugated construction panel disclosed herein; and a second construction panel onto the first construction panel, wherein the second construction panel is the corrugated construction panel disclosed herein.

[0095] In any or all of the above aspects, the first construction panel and second construction panel form a single overlap gap ranging from 1 millimeter to 10 millimeters; and a double overlap gap ranging from 5 millimeters to 20 millimeters.

[0096] In any or all of the above aspects, the single overlap gap has a range from between 2 millimeters to 5 millimeters; and the double overlap gap has a range from 10 millimeters to 15 millimeters.

[0097] A method of making the making a corrugated panel is also disclosed herein, the method comprising: introducing a bamboo-based material; mixing the bamboo-based material with an adhesive; providing the mixture into a mold comprising a geometry for producing the bamboo-based construction panel disclosed herein; and pressing the mixture at a temperature ranging from 280°F to 400°F and under a pressure ranging from 2 MPa to 7 MPa.

[0098] In any or all of the above aspects, the bamboo-based material is made from non-woven bamboo strips, non-woven bamboo strands, bamboo fibers, bamboo particles, or any combination thereof.

[0099] In any or all of the above aspects, the adhesive comprises polymeric methylene diphenyl diisocyanate (pMDI), phenol formaldehyde (PF), melamine urea formaldehyde (MUF), or any combination thereof.

[0100] Also disclosed herein is a method comprising introducing a container having a height ranging from 1015 millimeters to 2035 millimeters; and providing 100 or more of the bamboo-based construction panel disclosed herein into the container, wherein the 100 or more bamboo-based construction panels are stacked.

VI. Examples

[0101] A numerical analysis package (*e.g.*, Abaqus® CAE) was utilized for establishing the material properties of the bamboo strand materials described in the following examples. Table 2 shows the material properties of the bamboo strands from the investigations conducted on individual strands to achieve the Young’s modulus along the major axis, E_1 ; the Poisson’s ratios along the three axes as shown in FIG. 3A, were estimated based on hardwood values known in the art; and the elastic moduli along the other axes were calculated based on Equation 1.

$$E_1 : E_2 : E_3 \approx 20 : 1.6 : 1 \text{ (Equation 1C)}$$

The shear modulus, G_{LR} , was further calculated from Equation 2.

$$E_1 : G_{12} \approx 14 : 1 \text{ (Equation 2)}$$

Table 2									
Material type	E_1 (GPa)	E_2 (GPa)	E_3 (GPa)	μ_{12}	μ_{13}	μ_{23}	G_{12} (GPa)	G_{13} (GPa)	G_{23} (GPa)
Elastic – Orthotropic	15.7	1.26	0.79	0.37	0.5	0.5	1.12	1.05	0.11

[0102] The calculated values were used to perform numerical simulations. The results of the numerical simulations are shown in FIG. 3B, which is a force-displacement graph of the linear region for each geometric configurations. The results shown in FIG. 3B graph were used to calculate the stiffness of each of the geometric configurations, wherein boundary conditions with displacement being applied on the center and the reaction forces being calculated and plotted with respect to the displacement.

[0103] A 3 level Analysis (*e.g.*, Taguchi analysis) accompanied by an additional analysis (*e.g.*, ANOVA Pareto analysis) was therefore used as a statistical tool for determining the parameters and the Design of Experiment (DOE).

[0104] *Taguchi Method*: Includes two aspects: (1) the signal to noise (S/N) ratios, and (2) the orthogonal array, ensuring all the parameters are observed at the same scale level. In short, it helps in developing a graphical study of the significant factors via the S/N ratio analysis. In addition, the Pareto-analysis of variance (ANOVA) is used for determining the contribution of each parameter in terms of the quantitative value. Thress of the methods in which Taguchi Analysis can be conducted include “smaller-is-better” for minimizing the response; “larger-is-better” for maximizing the response; and “nominal-is-best” for an average value response.

Example 1

[0105] In the example, the parameters of the A 3-level Taguchi analysis accompanied by Pareto-ANOVA analyses was carried out to for investigating the parameters of the corrugated non-woven bamboo composite panel.

[0106] The stiffness maximization was investigated by modifying the geometry for the current third generation (*e.g.*, Gen-3) panels, as disclosed herein. The second generation (*e.g.*, Gen-2) panels were the ones made in Phase I of the project. The various panel geometry parameters were investigated to produce a profile exhibiting desirable bending stiffness while maintaining a suitable geometry for the forming process that is transferable to the industry.

[0107] The “Larger-is-better” policy was used for investigating the S/N ratios, noise or variabilities of the selected factors and their three levels. The “Larger-is-better” method was utilized in the current example but the other two methods can be utilized. The selection of values representing the factors for achieving a suitable range and the respective levels are shown in Table 3, which were used to develop the L₉ design matrix for performing the 3-level Taguchi analysis.

Table 3												
Variation	A-Depth (mm)			B-Pitch (mm)			C-Rib Span (mm)		D-Rib Radius (mm)			
Values	20	27	35	80	120	160	15	25	35	10	13.5	17.25
Assigned #	1	2	3	1	2	3	1	2	3	1	2	3

[0108] Nine designs were investigated, which are illustrated in FIGS. 4A-4I, by plotting their respective Signal to noise (S/N) ratios. The S/N ratios were calculated from Equation 3.

$$\frac{S}{N} \text{ ratio} = -10 \log \left(\frac{\sum (1/y^2)}{n} \right) \text{ (Equation 3)}$$

where, *n* represents the number of samples for each trial (*n*=1), and *y* is the response value obtained from the L₉ matrix.

[0109] The corresponding S/N ratios were plotted and are shown in FIGS. 6A-6D. FIG. 6A shows the depth of the corrugated panel; FIG. 6B shows the pitch of the corrugations; FIG. 6C shows the rib span of the corrugated profile; and FIG. 6D shows the rib radius of the spans. FIGS. 6A-6D demonstrate that the stiffness is greater when the depth is highest at 35 mm, the pitch is lowest at 80 mm, the rib span is highest at 35 mm, and the rib radius is at 13.5 mm. The variation in noise

can also be observed to be the highest for the depth of the panels, while pitch, rib span and rib radius have low variations.

[0110] The Pareto-ANOVA analysis quantifies the influence of each parameter on the final stiffness value. FIG. 6E demonstrates that the influence of depth is the highest at 83.8%; the pitch and rib span had similar influence of 7.5% and 8.5%, respectively; and the rib radius had minimal influence. Thus, the change in rib radius did not influence the stiffness of the panel and the change in the pitch had minimal influence on the stiffness.

[0111] Therefore, using the “larger-is-better” technique for panel stiffness, the following geometric parameters provided the highest response value: depth of 35 mm; pitch of 80 mm; rib span of 35 mm; and rib radius of 13.5 mm.

[0112] FIG. 4 is a schematic drawing showing the comparator, which includes a geometry as per the current (IS). As previously discussed, such a profile has many limitations, including reduced stiffness, one dimensional use due to minimal bond area for sandwich structures, and higher resin content. In contrast to the comparator, this example demonstrates desirable geometric parameters such as, but not limited to, the pitch varying between 80 mm and 160 mm, depth varying between 20 mm and 35 mm, rib span varying between 10 mm and 35 mm, and rib radius varying between 8 mm and 17.25 mm.

Example 2

[0113] In this example, the interfacial shear strength between the outer plies and the core at the bond interface was investigated. The parameters were further investigated for their suitable forming, repeatability of the panel fabrication, ability, bond area for sandwich structure, and gap formation during roofing assembly

[0114] The shear strength was simulated with two 0.25 inch (6.35 mm) thick face-sheets, which are illustrated in FIG. 7. The panels were again loaded in bending, as per the Indian Standard, and the same force-displacement graph was used to calculate the interfacial shear stress, using Equation 4.

$$\tau_{interfacial} = \frac{V}{EI} \left[\frac{E_f t_f d}{2} \right] \text{ (Equation 4)}$$

Where, V is the reaction force from bending loads, EI is the stiffness of the assembly, E_f is the Young's modulus of the face-sheet, t_f is the thickness of the face-sheet, and d is the total thickness of face-sheet and the height of the core (t_c).

[0115] Interfacial shear stresses as that of the established and tested sandwich panel were used for the sandwich panel, referred to as the WS panels, which are thin-walled hollow-core wood strand sandwich panels. The peak force under bending for the wood-strand sandwich panels was considered as V for calculating the interfacial shear strength of the panel.

[0116] The calculated interfacial shear stress, using Equation 4, was 0.16 MPa and was further used as the interfacial shear stress of the new sandwich structure, using which the maximum load was back calculated to understand the load bearing capacities. The load bearing capacities of the WS panels was 3.8 kN, which was calculated to be 3.1 kN for the new panels. Experimental values were used to calculate the interfacial shear stress of the WS panels, with actual slopes. The following factors were also considered: bamboo's greater stiffness relative to wood; the influence of the bond area of the established WS panels; and the thickness of the core panels (50% of the amount of used in the WS sandwich panels). FIG. 8 is a schematic drawing showing aspects of the two-dimensional profile of the panel comprising the parameters determined above.

[0117] The pitch was increased to 120 mm to achieve a more desirable slope angle that could be easily formed. The updated 2-dimensional drawing is illustrated in FIG. 9A, along with the 3-dimensional corrugated profile shown in FIG. 9B.

[0118] The first generation (*e.g.*, GEN-1) panels were made from woven bamboo strips, whereas the current third generation (*e.g.*, GEN-3) panels are to be made from bamboo strands. The panels provided in the comparator (IS), are 3.8 mm thick, which was possible because three layers of woven bamboo mats were used. However, when forming the nonwoven mat of bamboo strands, adequate layers of strands through the thickness in any given location on the mat were provided to avoid introducing voids and weakening the final panel strength. Therefore, the thickness of the panels was increased to 6.35 mm (0.25 inch). The strand thickness was also reduced to have a thickness ranging from 0.01" to 0.02", or 0.25 mm to 0.5 mm. The panel thickness of 6.35 mm exhibited desirable strength and stiffness, with thinner strands providing uniform coverage across the mat to form an even panel with uniform densities throughout the panel.

[0119] FIG. 10A is an image of a second generation (e.g., GEN-2) panel comprising a transverse rib along with the longitudinal ribs. The bond area of the GEN-2 panel comprising a transverse rib was compared to a panel with no transverse rib. FIG. 10B is a bar graph showing the GEN-2 panel comprising a transverse rib bond area of 1266 in² (0.82 m²) and the GEN-2 panel without a transverse rib having a bond area of 691 in² (0.45 m²). Therefore, the overall bond area was calculated to be almost two-fold. To maintain the depth at 35 mm and achieve additional stiffness without modifying pitch, the rib radius was decreased to 10 mm to increase the bond area, which is referred to as the E-Panel. Accordingly, the total bond area increased by 50%, 1033 in² (0.7 m²) compared to 0.82 m² of the second generation (e.g., GEN-2) panel as demonstrated in FIG. 10B.

[0120] In order to form a mat that will be pressed in the desired geometry, the flattened length of the design was also investigated. The press width was 1489.08 mm (58.625”), whereas the E-panel’s flattened length was 1565.66 mm (64.26”). Thus, further investigations were carried out with varying geometry parameters to achieve the desired flattened length. The various studied designs are described in Table 4 where “D” is the Design, “d” is the panel depth, “P” is the pitch, and is “A” is the angle.

Design (D) #	Geometry	Flattened Length (mm)
D-0	P = 120 mm; d = 22 mm; A = 51.29°	1435.66
D-1	P = 150 mm; d = 35 mm; A = 51.29°	1565.66
D-2	P = 150 mm; d = 33 mm; A = 51.29°	1549.4
D-3	P = 150 mm; d = 30 mm; A = 51.29°	1525.02
D-4	P = 150 mm; d = 30 mm; A = 50°	1516.89
D-5	P = 150 mm; d = 30 mm; A = 48°	1508.76
D-6	P = 150 mm; d = 26 mm; A = 51.29°	1486.92
D-7	P = 150 mm; d = 27 mm; A = 51.29°	1500.63
D-8	P = 150 mm; d = 30 mm; A = 45°	1486.92

[0121] A numerical analysis was further carried out on D-0, D-6 and D-8 and compared to the previous embodiments and the comparator panel (IS). The designs with nomenclature M are illustrated in FIGS. 1A-1D and FIG. 11A is a schematic drawing showing the dimensions of the comparator, Indian Standard 15476 (IS Panel). FIG. 1A is a schematic drawing showing aspects of the bamboo-based composites disclosed herein (Model-0/M-0) comprising a pitch of 120 millimeters, a depth of 35 millimeters, and a slope angle of 51.29°. FIG. 1B is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 120 millimeters, a depth of 22 millimeters, and a slope angle of 51.29° (Model-1/M-1). FIG. 1C is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a

pitch of 150 millimeters, a depth of 30 millimeters, and a slope angle of 51.29° (Model-2/M-2).

FIG. 1D is a schematic drawing showing aspects of the bamboo-based composites disclosed herein comprising a pitch of 150 millimeters, a depth of 35 millimeters, and a slope angle of 45° (Model-3/M-3).

[0122] Flexural analysis was again performed in Abaqus[®], and the comparisons between the designs are provided in FIGS. 12A-12B. The bending stiffness comparison shown in FIGS. 12A-12B, demonstrates that although M-0 had the highest value, M-3 exhibited a desirable performance, exhibiting an 185% higher stiffness relative to the IS panel and about 25% lower stiffness than M-0. The interfacial shear stress comparison shows that the IS-panel had the highest stress concentration, followed by M-3, and the lowest in M-0. The interfacial shear stress was 170% lower than the IS-panel and only about 19% higher than the previously obtained design, M-0.

[0123] The bond area was recalculated for the sandwich panels. The M-3 design was calculated to have a bond area of 1067.5 in² (0.69 m²), which was about 3% higher than the E-panel but about 16% less than the Gen-2 panels. The rib radius was reduced to 8 mm as illustrated by the schematic drawing shown in FIG. 1E (Model-4/M-4), which increased the bond area to 1209 in² or 0.8 m². Model-4 had the greatest bond area relative to the other models investigated and 4.5% lower than the Gen-2 panels. Numerical analysis with the aid of Abaqus[®] was further performed to investigate the change in stiffness and interfacial shear stresses. The results demonstrate that M-4 had a 1.2% in bending stiffness decrease and a 1.2% increase in interfacial shear stress.

[0124] FIG. 13 is an illustration of the 3-D panel used to manufacture the mold with the third generation (*e.g.*, GEN-3) panel geometric parameters comprising a depth a depth of 30 mm; a pitch of 150 mm; a rib span of 46.63 mm (corner to corner) and 40 mm (flat); and a rib radius of 8 mm.

Example 3

[0125] In this example, the stackable geometry and a roofing assembly comprising the non-woven bamboo composite panels disclosed herein were investigated.

[0126] The panels had a height of 6 inches or 152.5 millimeters and are to be generally shipped in pallets. The conventional packing height is 48 inches (1219.2 millimeters), which leaves about 42 inches (1066.8 millimeters) for the product and therefore 116 of the panels can be shipped together on a pallet, more than M-0. The parameters therefore increased by 8.98 ± 0.13 millimeters (0.3535 ± 0.01 inches) per panel during stacking.

[0127] The roofing assembly of the third-generation bamboo roofing panels are shown in FIG. 15A. During the assembly process, the overlap gaps between the panels provide additional ventilation to the building, which are desirable in low-income housing units. FIG. 15B shows that the minimum gap achieved from a single overlap was 2.6 mm and the maximum gap achieved from a double overlap was 11.6 mm. These were then compared to Indian Standard panels, as illustrated in FIG. 15C. The single overlap gap in the Indian sinusoidal panels was 1.92 mm and the double overlap gap was 10.18 mm. As such, the 14% increase and 1.4 mm increase in gaps of the panels disclosed herein was desirable.

Example 4

[0128] In this example, the mold for producing the panels disclosed herein was investigated. The resultant bamboo strand panels after being mixed with an adhesive was formed by pressing within the mold at a suitable temperature and pressure. FIG. 16 is a schematic drawing showing a mold assembly for producing GEN-3 panels comprising a depth of 30 mm, pitch of 150 mm, rib span of 40 mm (flat), and rib radius of 8 mm. The thickness of the panels was 6.35 mm, to produce stiffer and high utility panel fabrication.

[0129] In view of the many possible aspects to which the principles of the present disclosure may be applied, it should be recognized that the illustrated aspects are only preferred examples of the present disclosure and should not be taken as limiting the scope of the present disclosure. Rather, the scope of the disclosure is defined by the following claims. We therefore claim as our invention all that comes within the scope and spirit of these claims.

We claim:

1. A corrugated non-woven bamboo composite panel, comprising:
 a thickness ranging from 1 millimeter to 10 millimeters;
 a plurality of top rib spans and bottom rib spans forming a plurality of slopes
 comprising a rib radius ranging from 5 millimeters to 15 millimeters;
 a corrugation depth ranging from 5 millimeters to 50 millimeters measured from a
 lower portion of the lower rib spans to a lower portion of the top rib spans; and
 a pitch ranging from 50 millimeters to 200 millimeters measured from a center
 portion of the top rib spans.

2. The corrugated non-woven bamboo composite panel of claim 1, wherein the
 plurality of slopes comprise one or more upward slopes and one or more downward slopes, and
 wherein the one or more upward slopes and the one or more downward slopes have a slope angle
 ranging from 40 degrees to 60 degrees.

3. The corrugated non-woven bamboo composite panel of claim 1, wherein the lower
 rib span has a thickness (t), rib span (s), rib radius (r), corrugation depth (d), and pitch (p) according
 to Equation 1A, and wherein the upper rib span has a thickness (t), rib span (s), rib radius (r),
 corrugation depth (d), and pitch (p) according to Equation 1B:

$$t_l = 0.109s_l = 0.475r_l = 0.633d_l = 0.03166p_l \text{ (Equation 1A)}$$

$$t_u = 0.069s_u = 0.64r_u = 0.183d_u = 0.04266p_u \text{ (Equation 1B)}.$$

4. The corrugated non-woven bamboo composite panel of claim 1,
 wherein:

the rib radius ranges from 8 millimeters to 15 millimeters;

the corrugation depth ranges from 6 millimeters to 35 millimeters; and

the pitch ranges from 120 millimeters to 155 millimeters.

5. The corrugated non-woven bamboo composite panel of claim 4, wherein the plurality of top rib spans and bottom rib spans have a length ranging from 25 millimeters to 95 millimeters.

6. The corrugated non-woven bamboo composite panel of claim 5, wherein:

the plurality of top rib spans and the plurality of lower rib spans have a length ranging from 25 millimeters to 95 millimeters;

the rib radius ranges from 5 millimeters to 10 millimeters;

the corrugation depth ranges from 25 millimeters to 35 millimeters; and

the pitch ranges from 145 millimeters to 155 millimeters.

7. The corrugated non-woven bamboo composite panel of claim 1, wherein the composite panel comprises a flattened length ranging from 1400 millimeters to 1600 millimeters.

8. A corrugated construction panel, comprising:

a bamboo-based material;

a plurality of top rib spans forming a plurality of upward slopes and a plurality of bottom rib spans forming a plurality of downward slopes having a slope angle ranging from 40 degrees to 60 degrees;

a thickness ranging from 3 millimeters to 7 millimeters; and

a load bearing capacity ranging from 3 N/mm to 5 N/mm.

9. The corrugated construction panel of claim 8, wherein the plurality of top rib spans and bottom rib spans have a length ranging from 35 millimeters to 50 millimeters.

10. The corrugated construction panel of claim 8, wherein the bamboo-based material has a bending load ranging from 600 N-m to 900 N-m.

11. The corrugated construction panel of claim 8, wherein the plurality of upward and downward slopes comprise a rib radius ranging from 5 millimeters to 12 millimeters.

12. The corrugated construction panel of claim 8, further comprising a corrugation depth ranging from 30 millimeters to 40 millimeters; and a pitch ranging from 120 millimeters to 150 millimeters.

13. A roofing assembly, comprising:
a first construction panel, wherein the first construction panel is the corrugated construction panel of claim 8; and
and a second construction panel onto the first construction panel, wherein the second construction panel is the corrugated construction panel of claim 8.

14. The roofing assembly of claim 13, wherein the first construction panel and second construction panel form a single overlap gap ranging from 1 millimeter to 10 millimeters; and a double overlap gap ranging from 5 millimeters to 20 millimeters.

15. The roofing assembly of claim 14, wherein the single overlap gap has a range from between 2 millimeters to 5 millimeters; and the double overlap gap has a range from 10 millimeters to 15 millimeters.

16. A method of making a corrugated panel, the method comprising:
introducing a bamboo-based material;
mixing the bamboo-based material with an adhesive;
providing the mixture into a mold comprising a geometry for producing the bamboo-based construction panel of claim 8; and
pressing the mixture at a temperature ranging from 280°F to 400°F and under a pressure ranging from 2.75 MPa to 6.2 MPa.

17. The method of claim 16, wherein the bamboo-based material is made from non-woven bamboo strips, non-woven bamboo strands, bamboo fibers, bamboo particles, or any combination thereof.

18. The method of claim 16, wherein the adhesive comprises polymeric methylene diphenyl diisocyanate (pMDI), phenol formaldehyde (PF), melamine urea formaldehyde (MUF), or any combination thereof.

19. A method, comprising:
introducing a container having a height ranging from 1015 millimeters to 2035 millimeters;
and
providing 100 or more of the bamboo-based construction panel of claim 8 into the container, wherein the 100 or more bamboo-based construction panels are stacked.

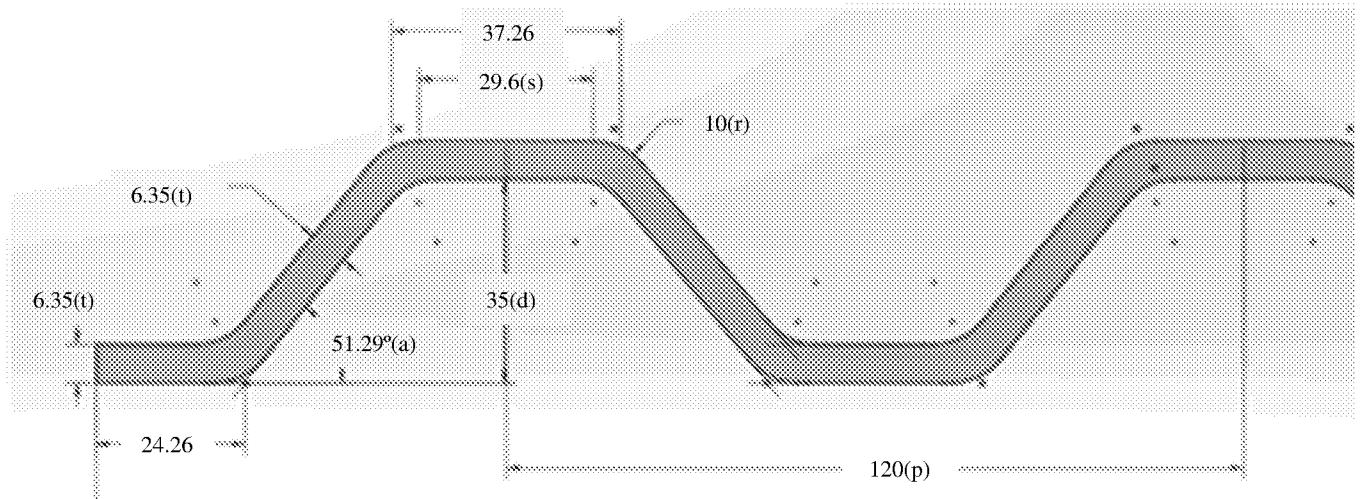


FIG. 1A

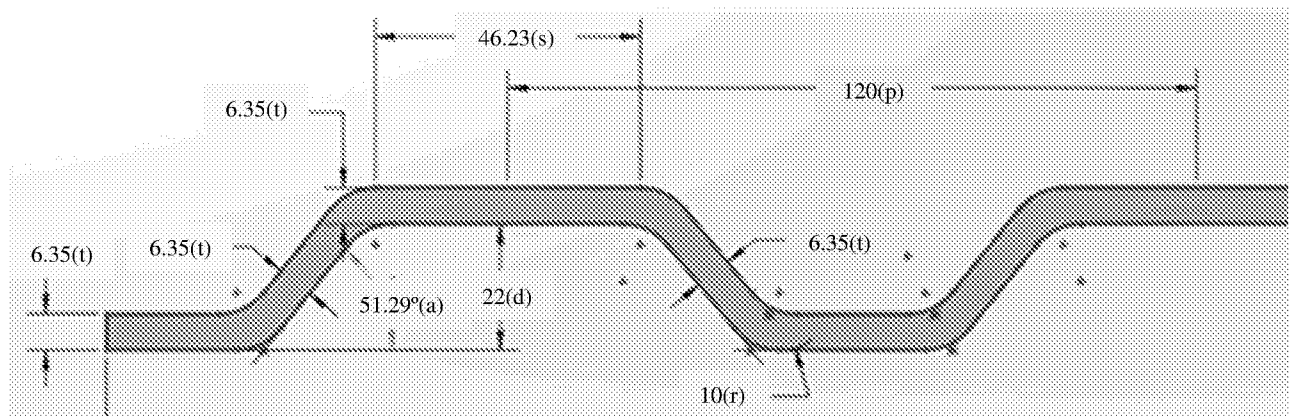


FIG. 1B

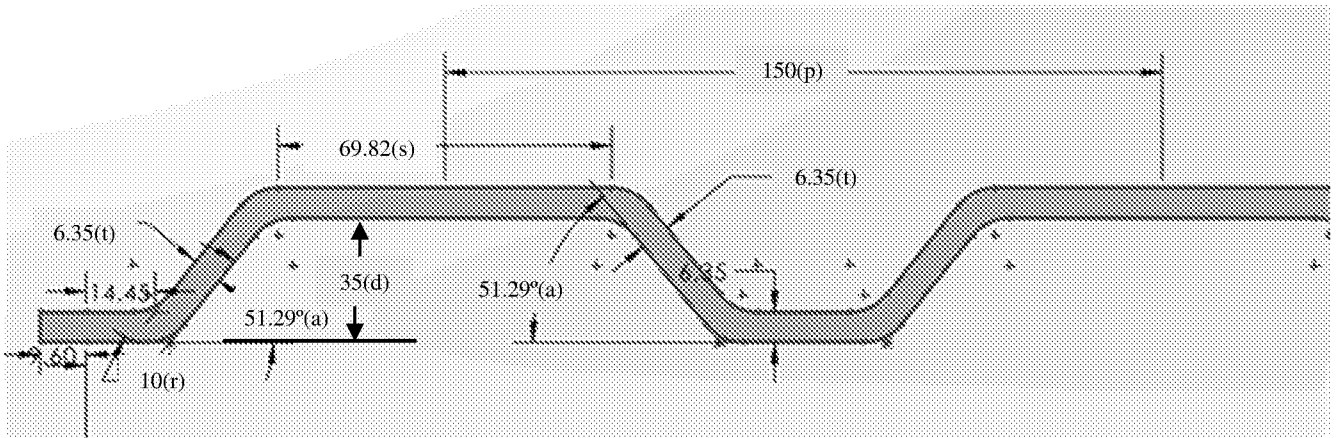


FIG. 1C

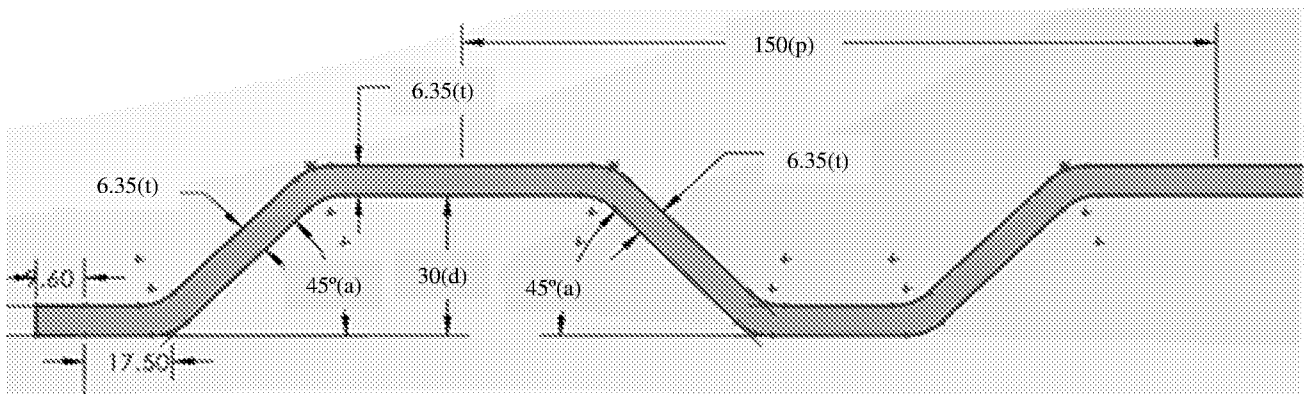


FIG. 1D

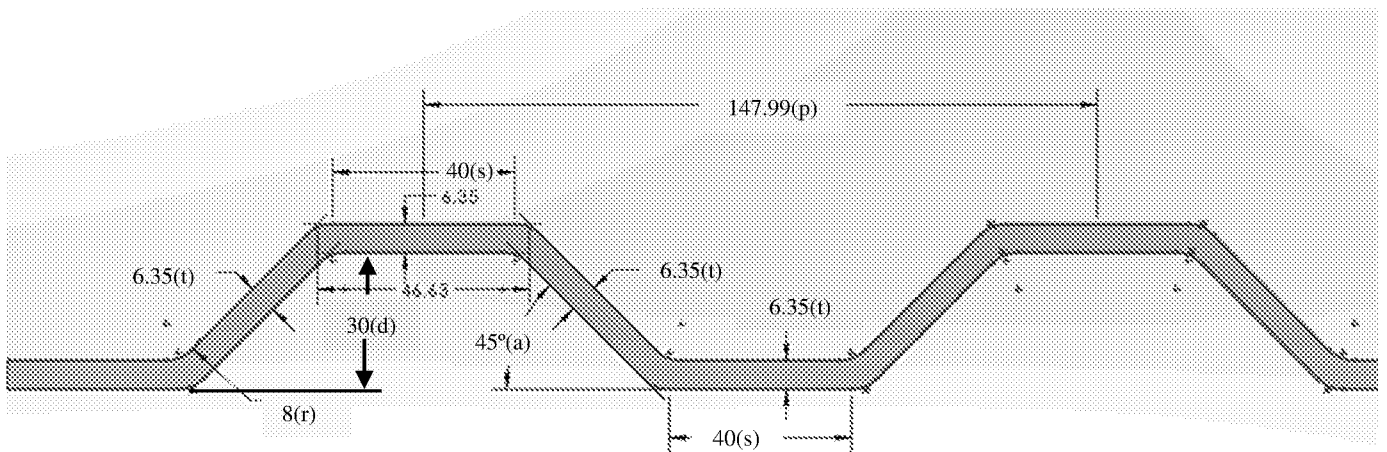


FIG. 1E

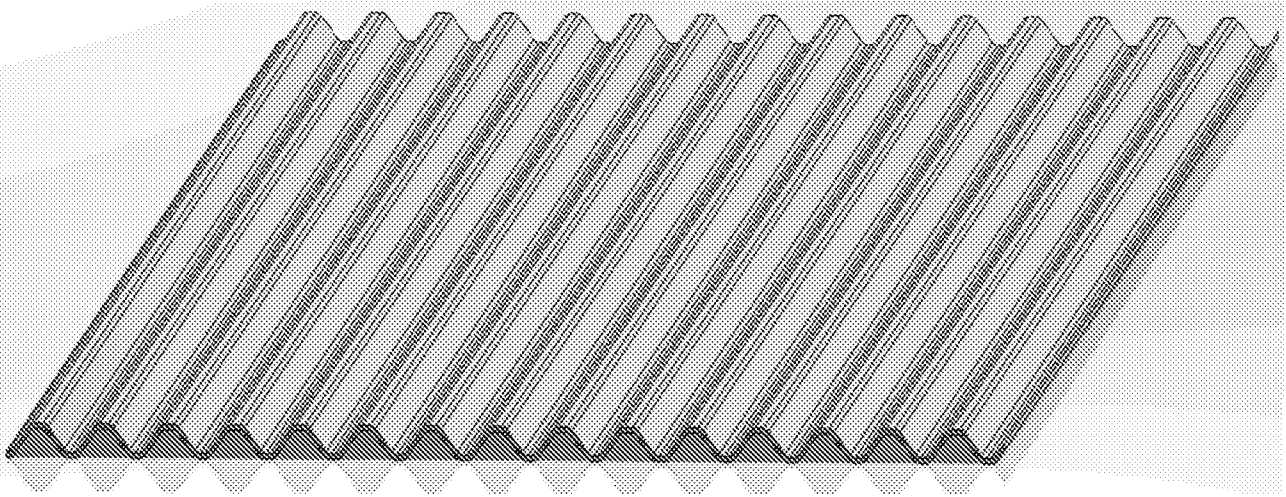


FIG. 2A

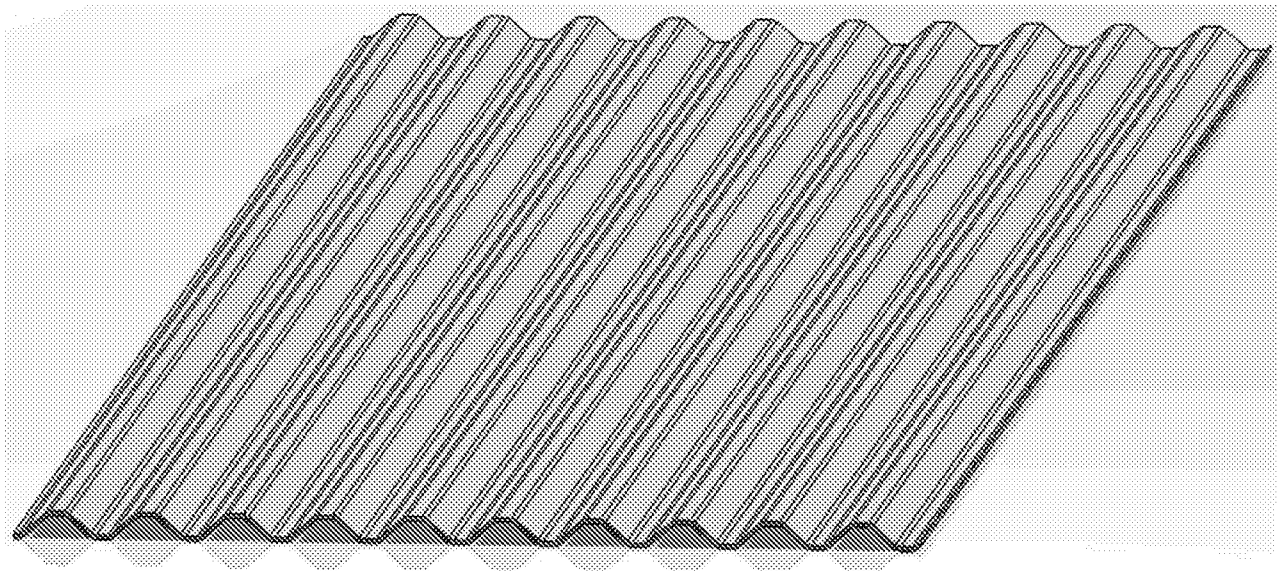


FIG. 2B

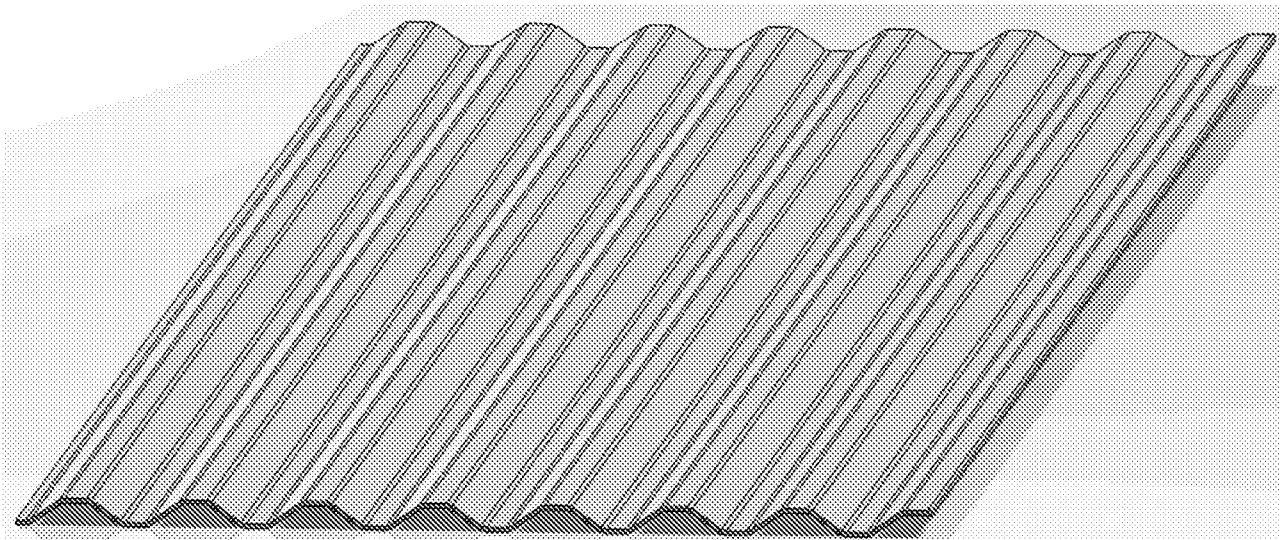


FIG. 2C

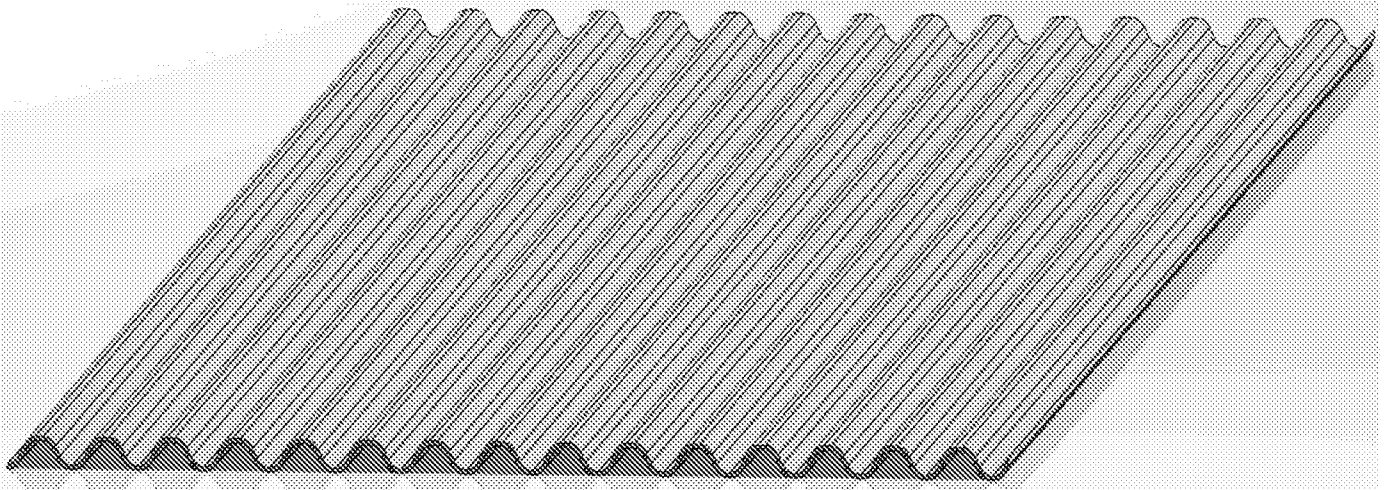


FIG. 2D

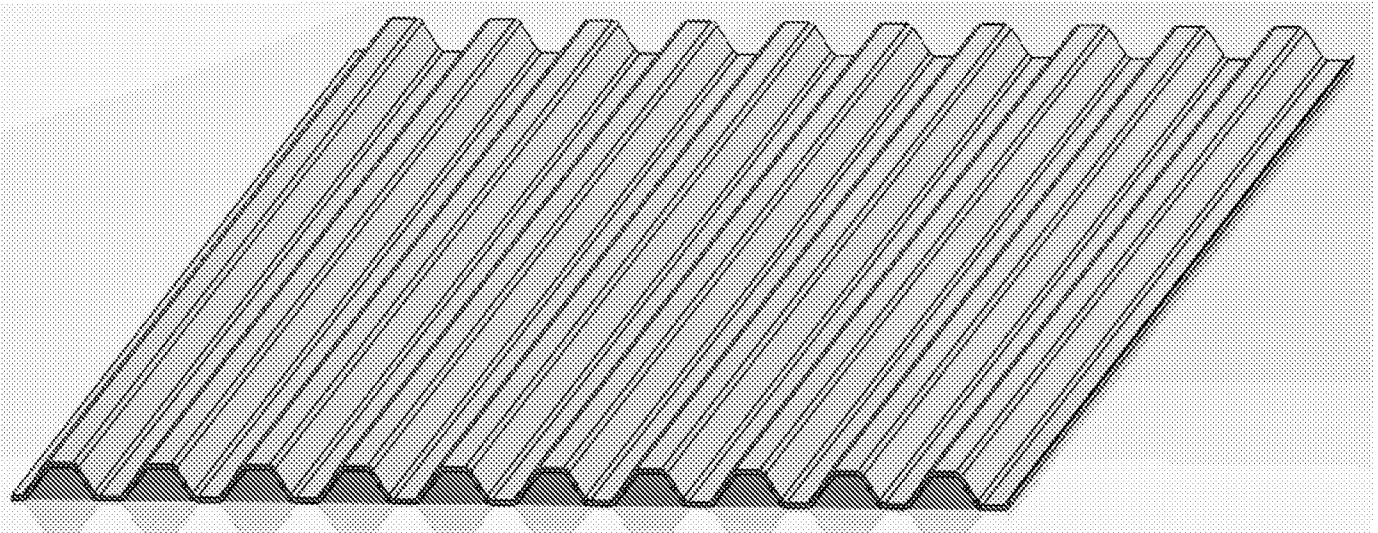


FIG. 2E

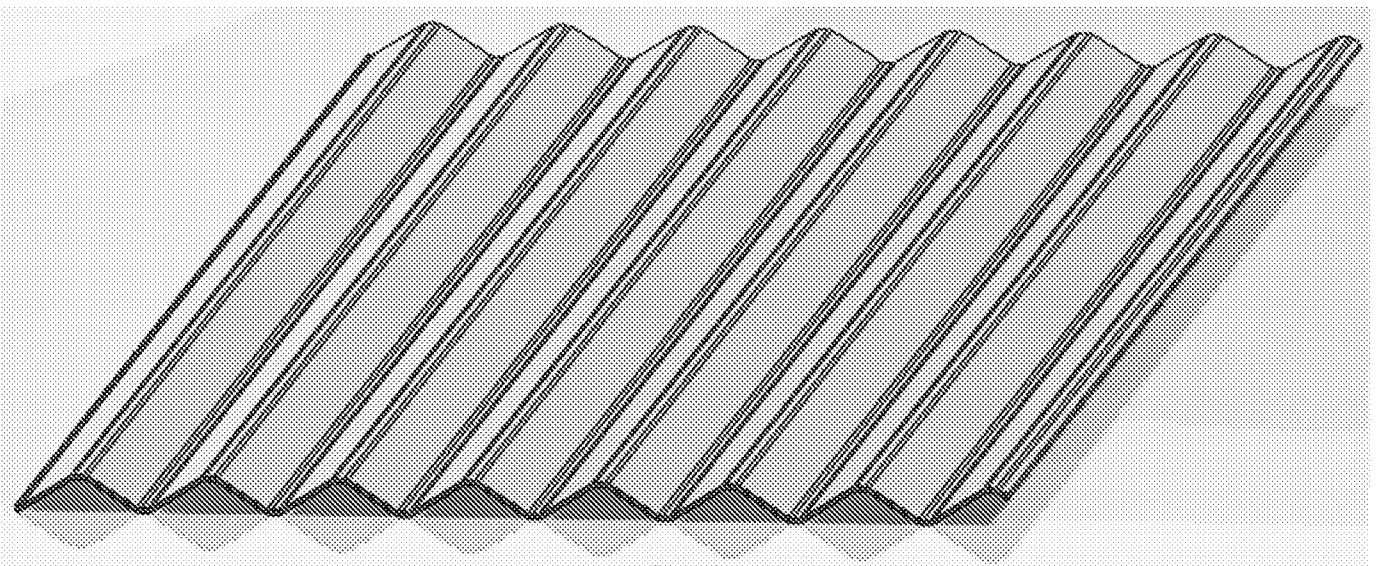


FIG. 2F

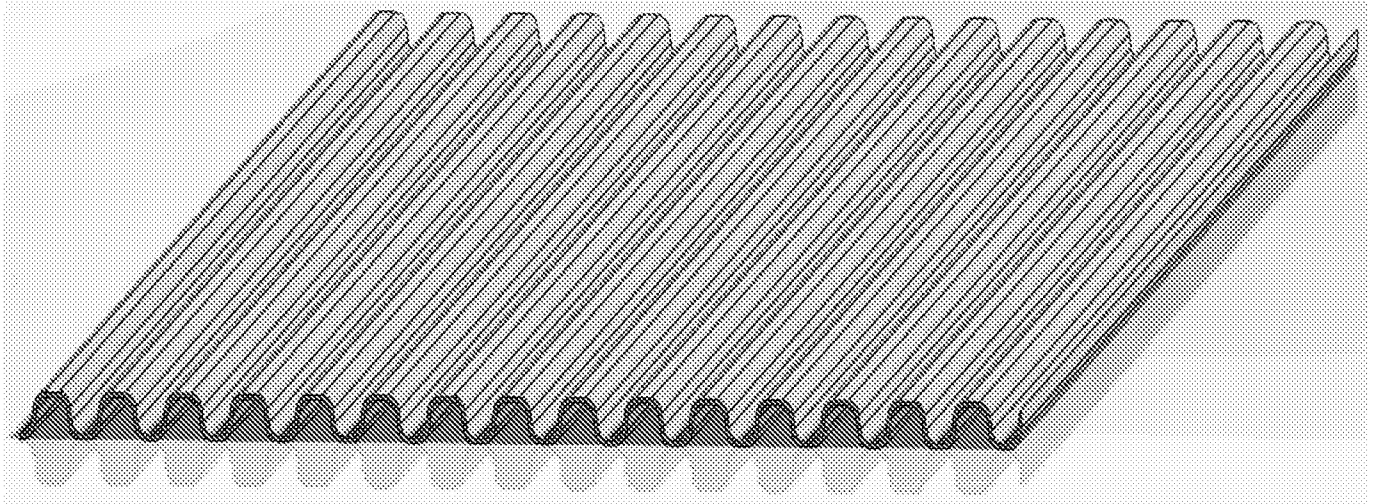


FIG. 2G

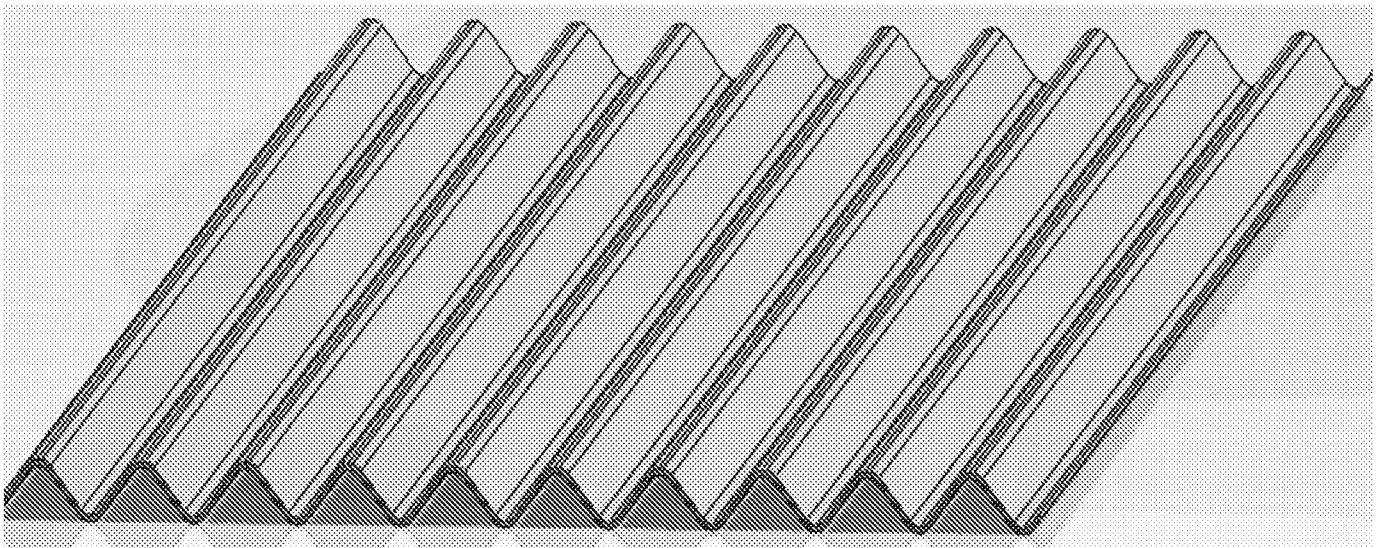


FIG. 2H

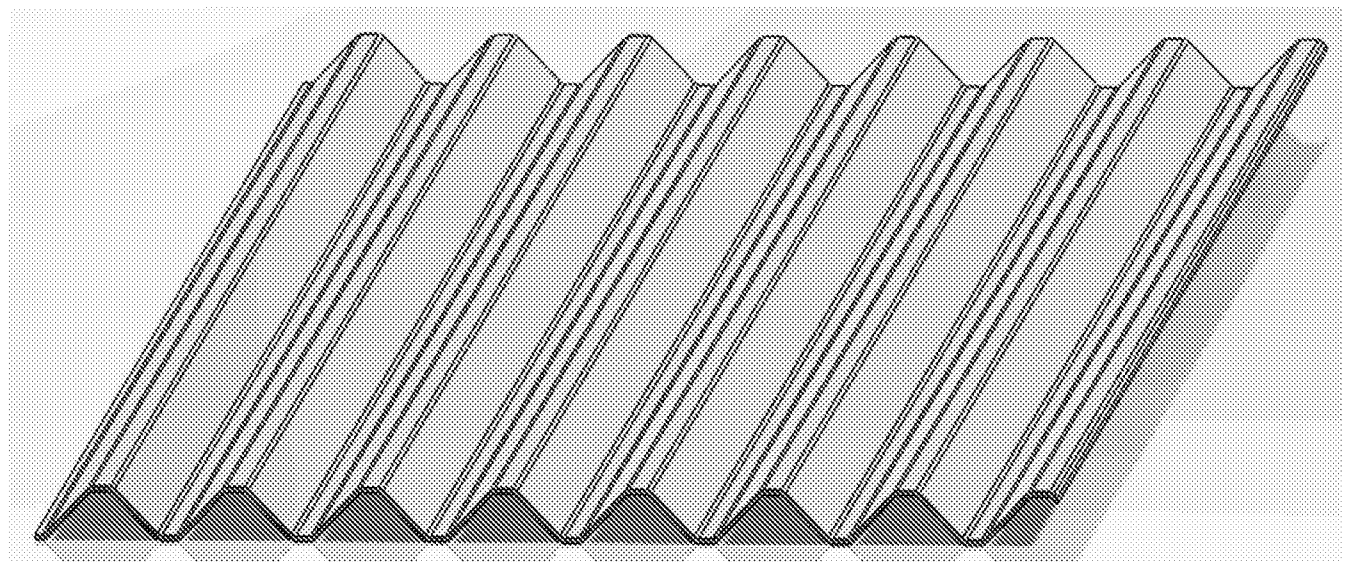


FIG. 2I

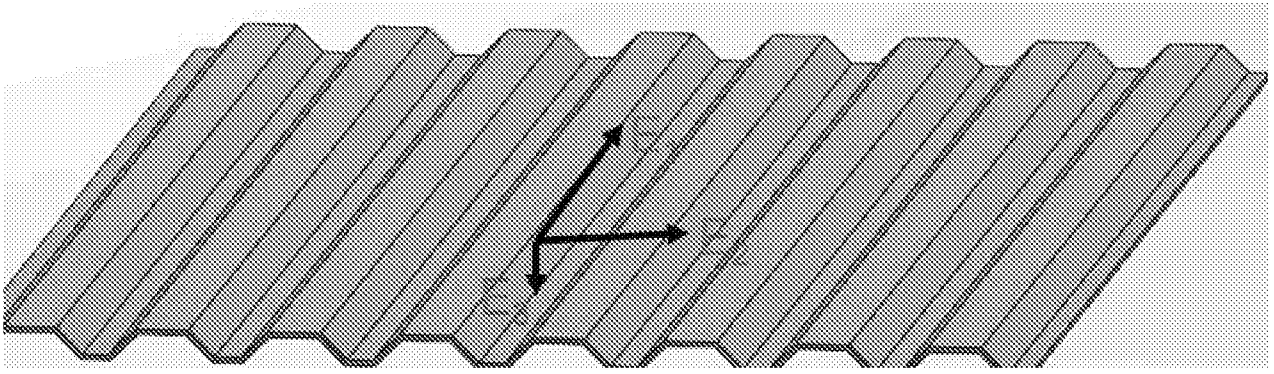


FIG. 3A

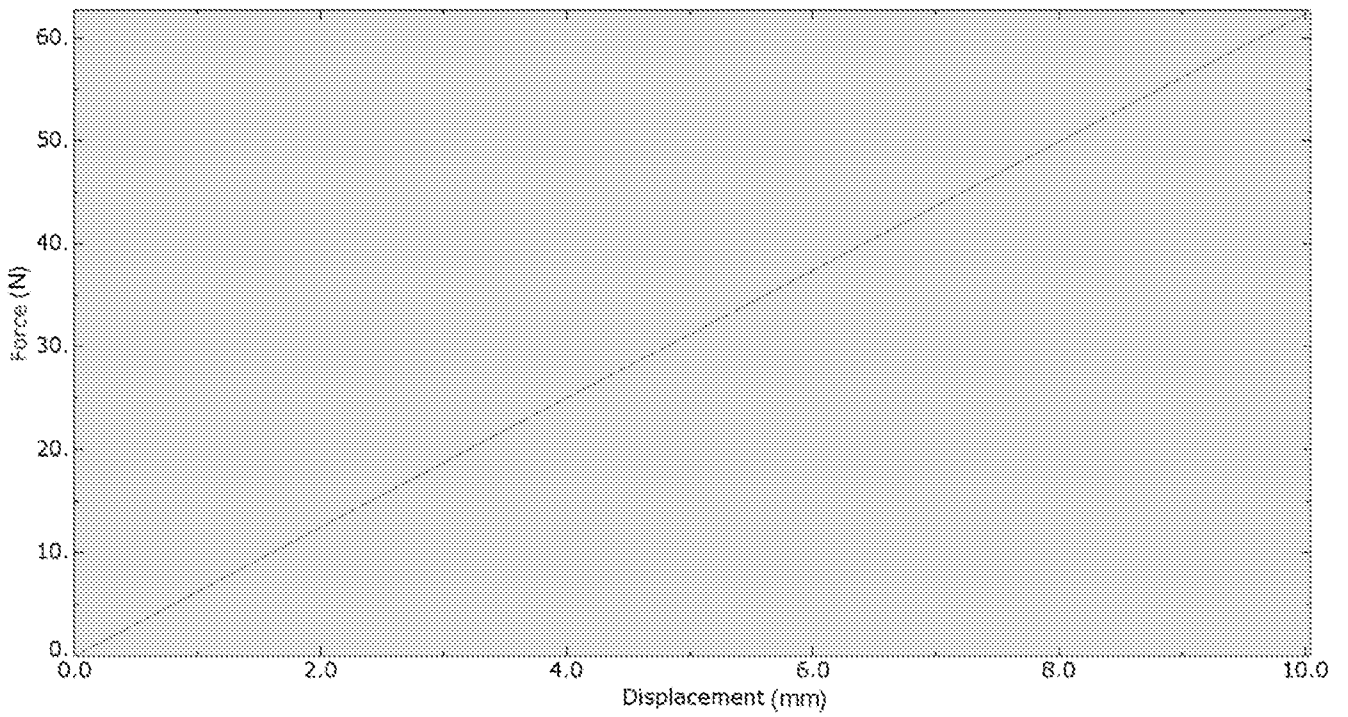


FIG. 3B

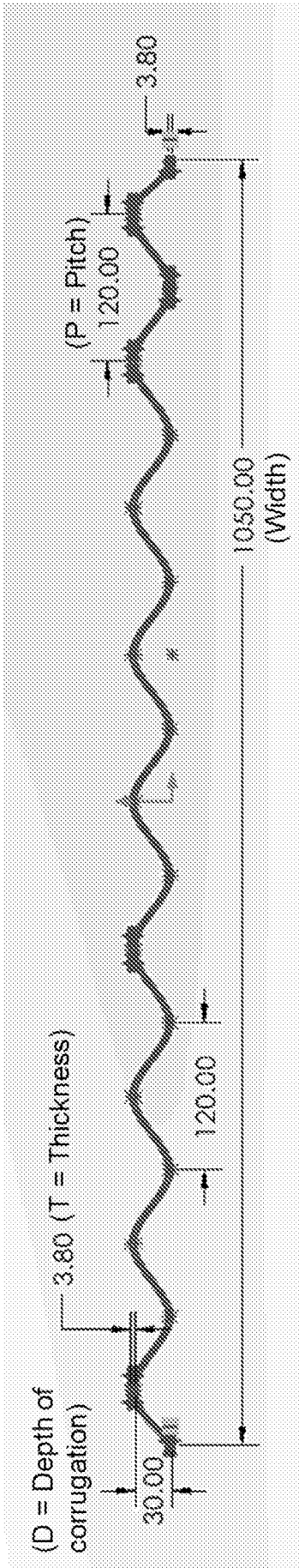


FIG. 4

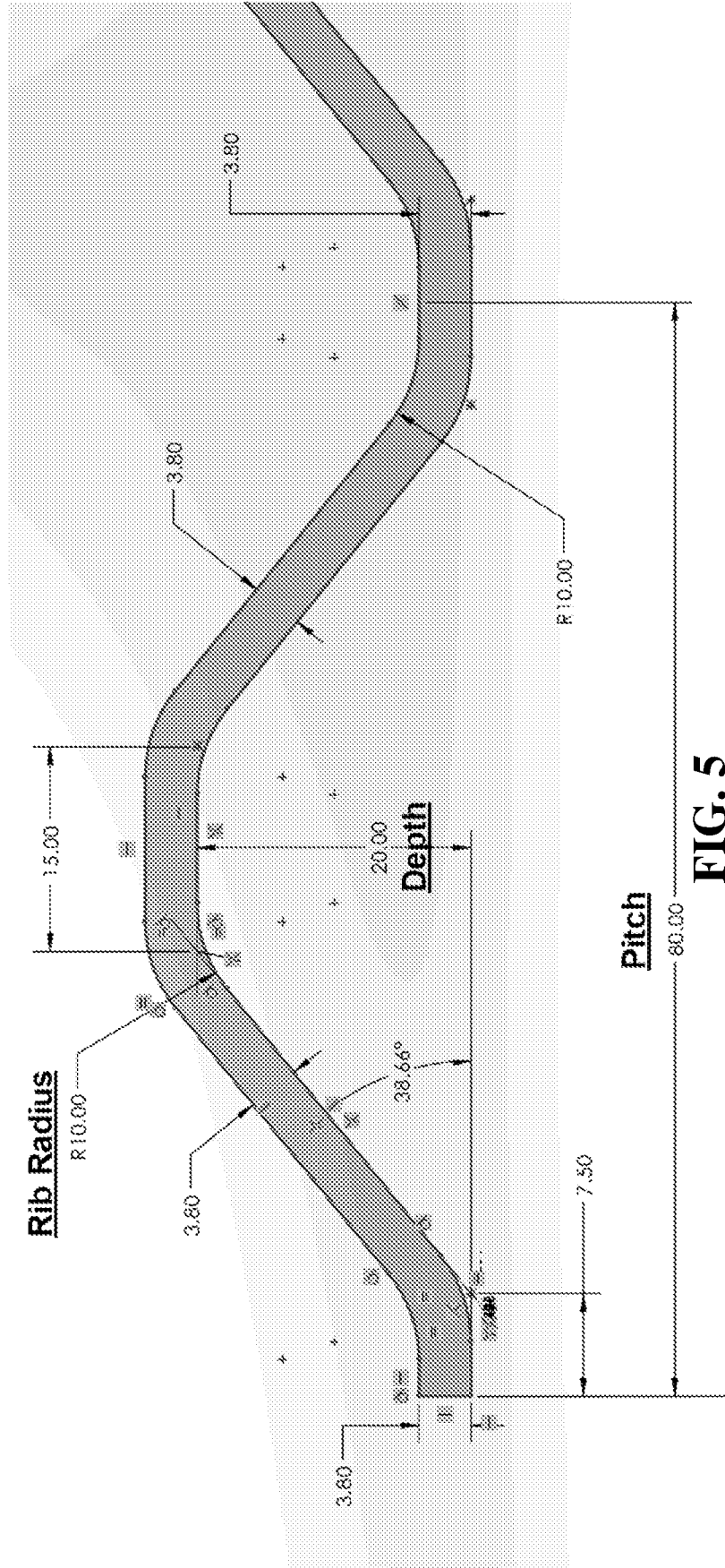


FIG. 5

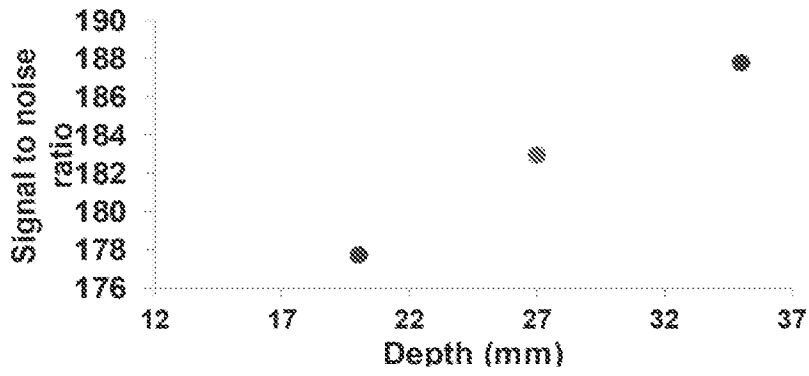


FIG. 6A

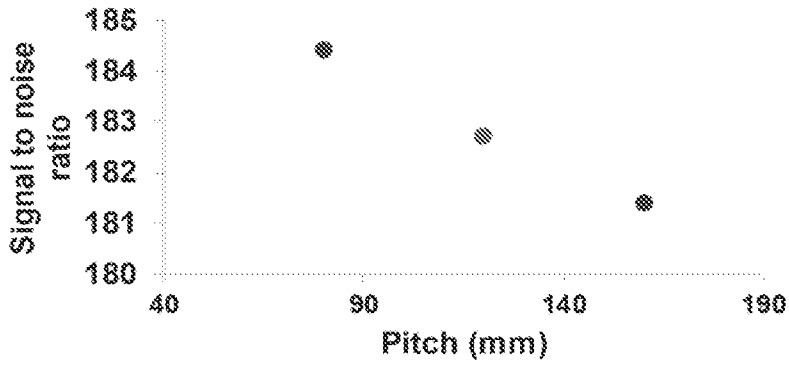


FIG. 6B

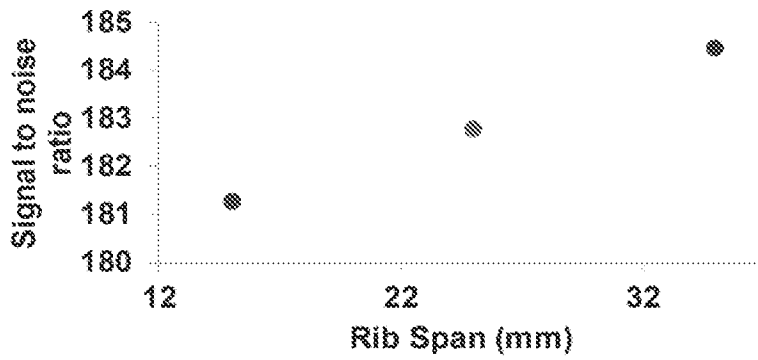


FIG. 6C

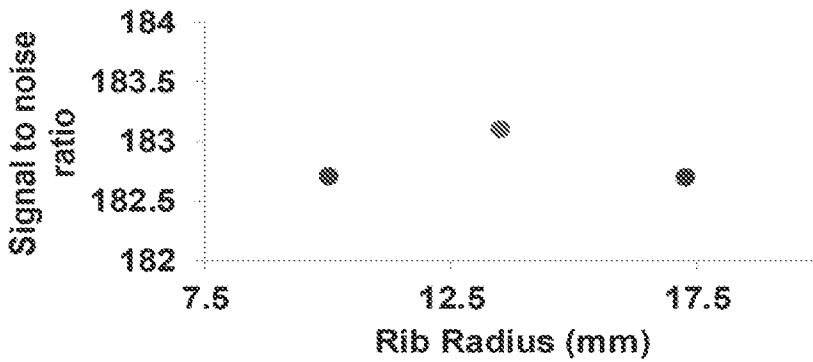


FIG. 6D

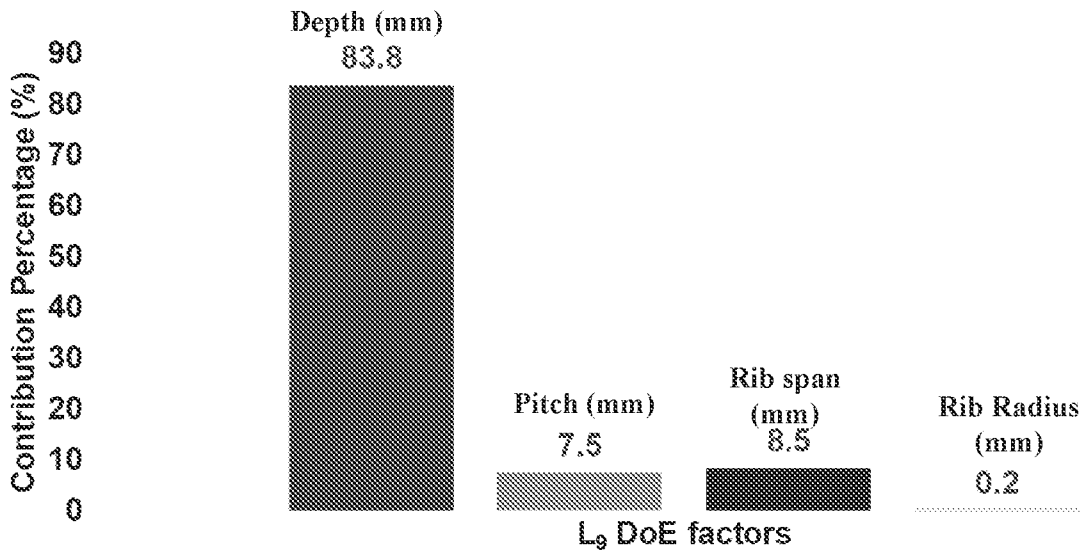


FIG. 6E

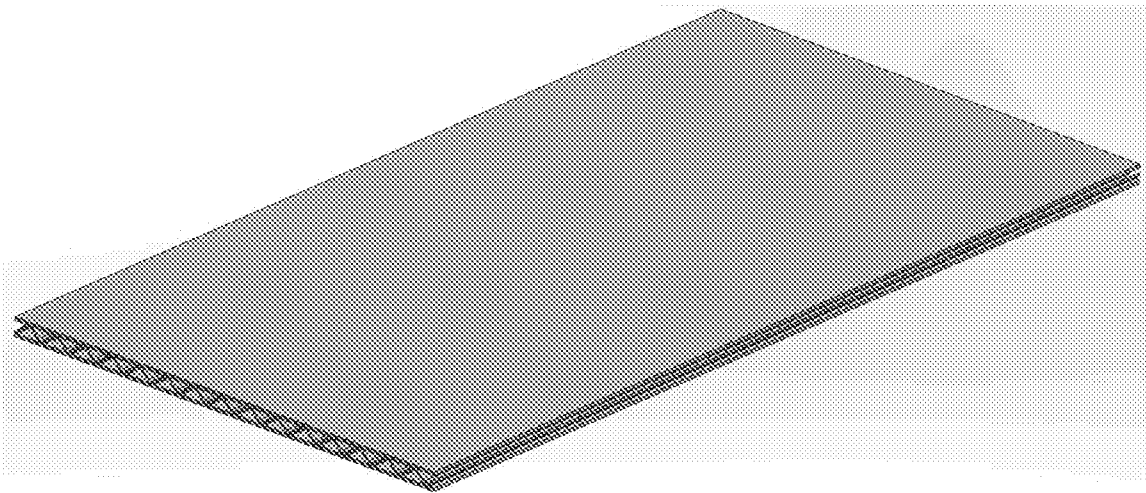


FIG. 7

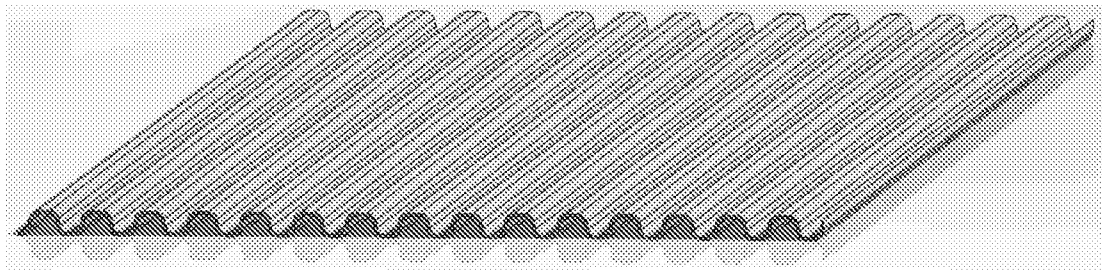


FIG. 8A

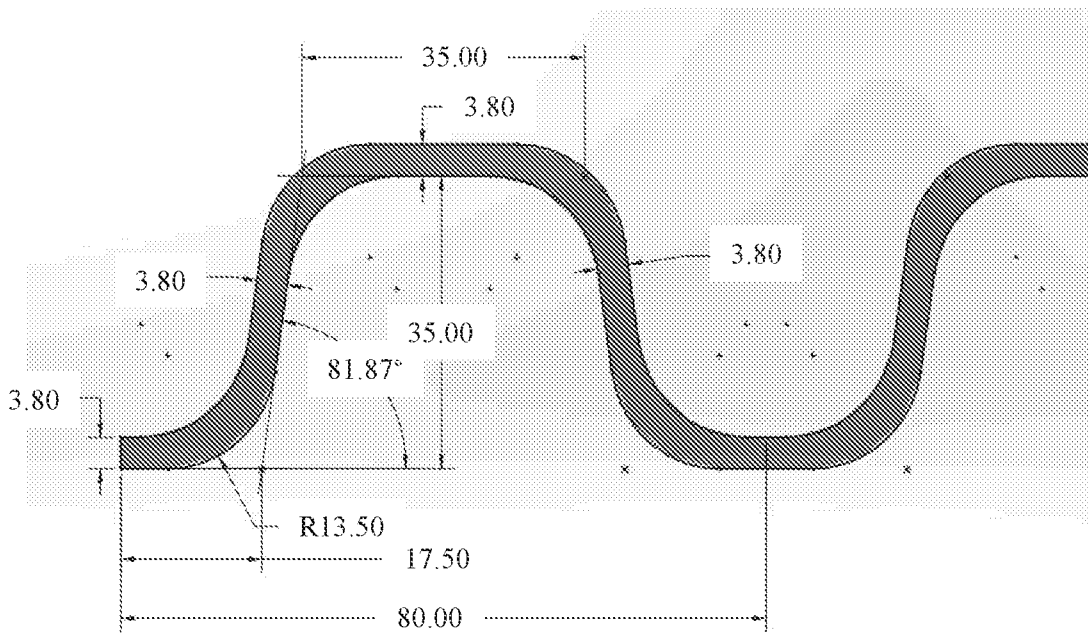


FIG. 8B

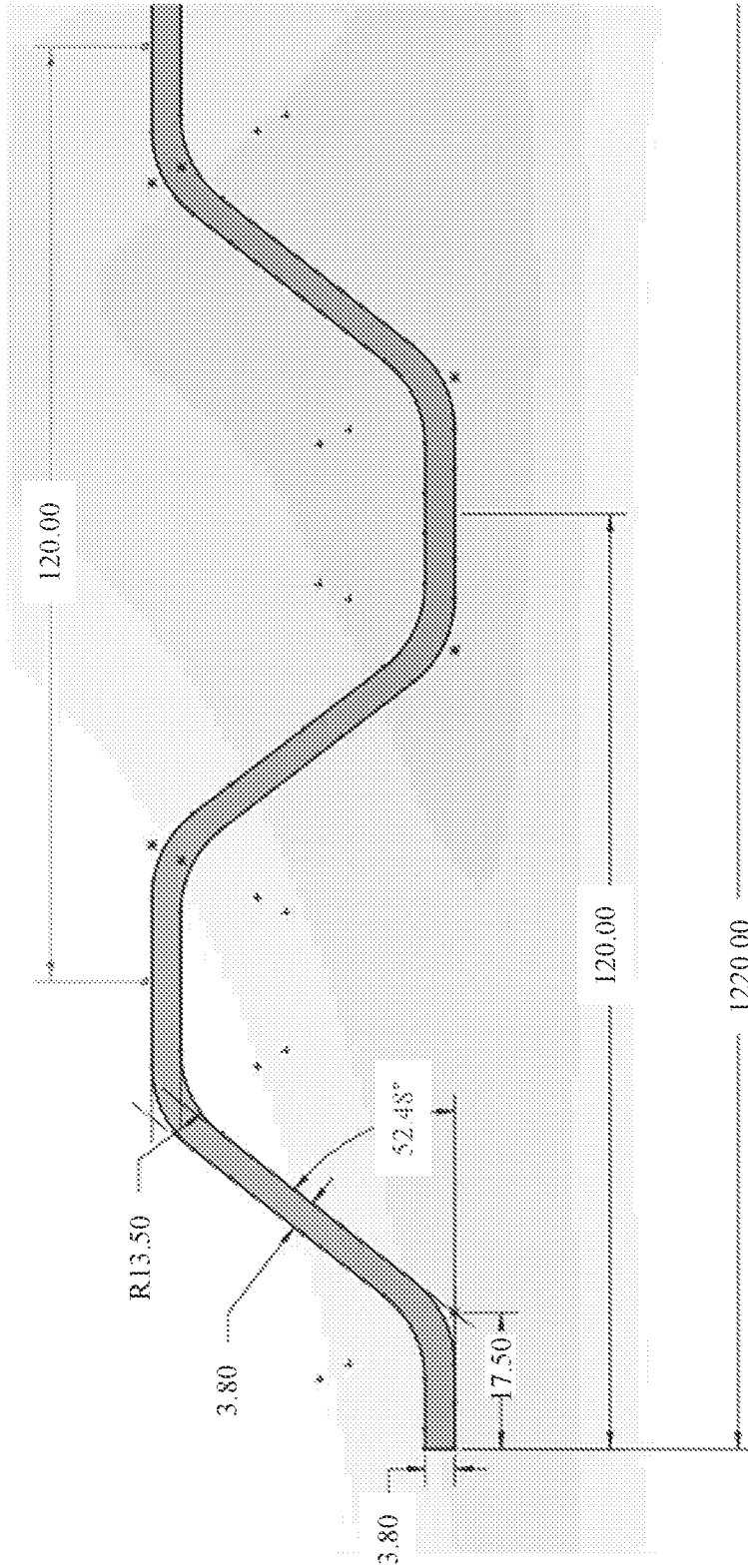


FIG. 9A

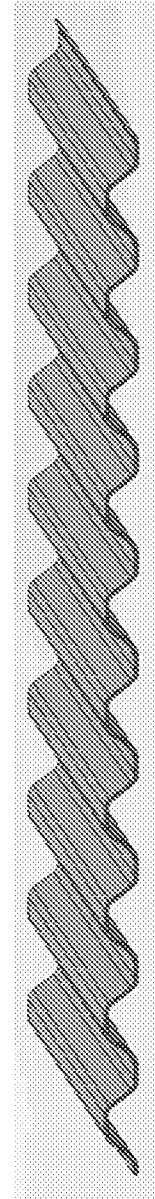


FIG. 9B

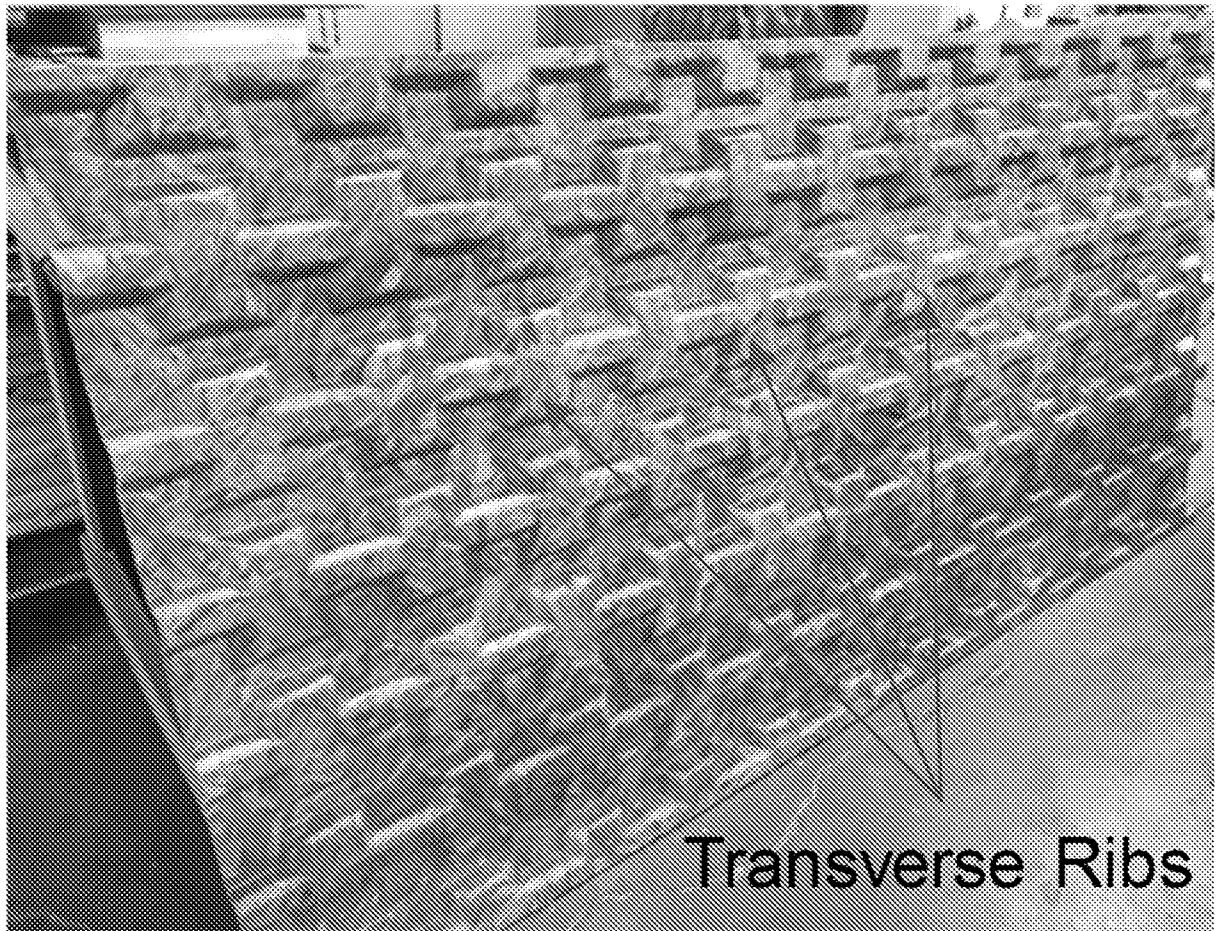


FIG. 10A

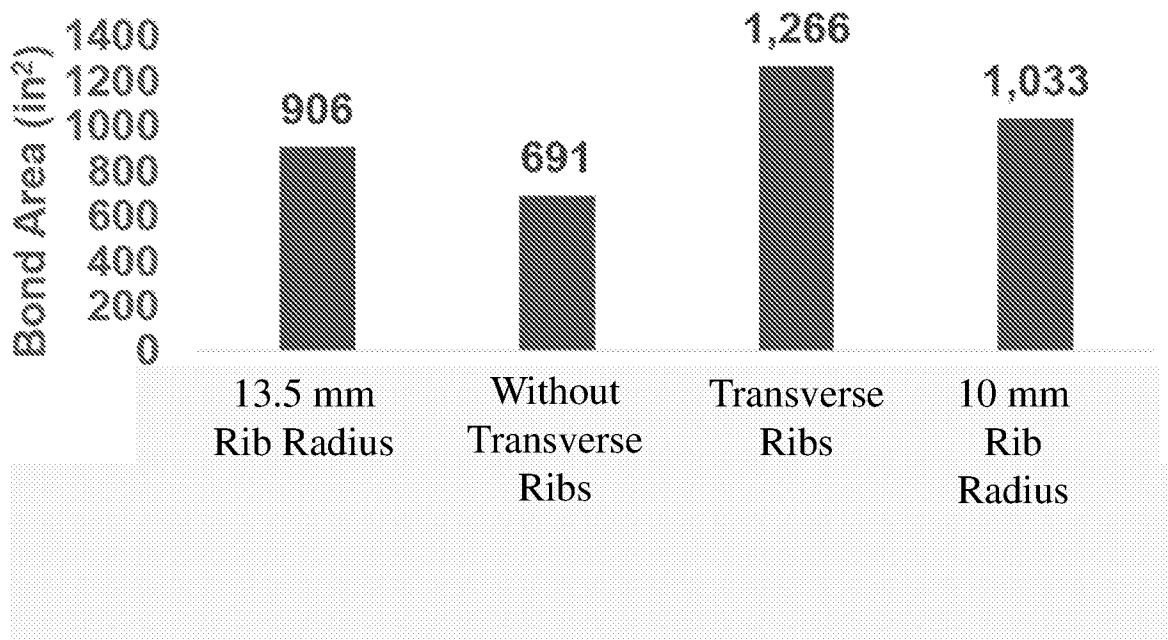


FIG. 10B

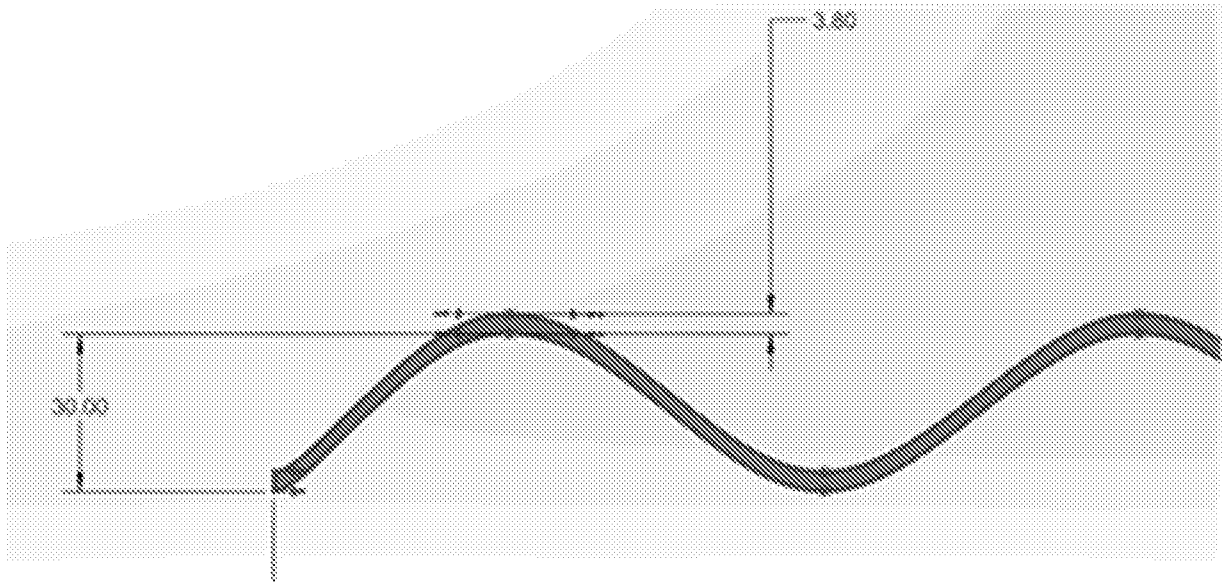


FIG. 11

Bending Stiffness = $D = EI$

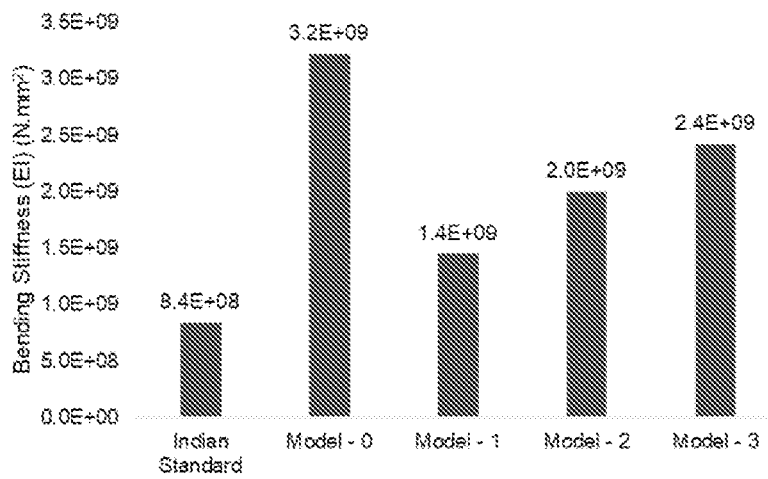


FIG. 12A

Interfacial Shear Stress

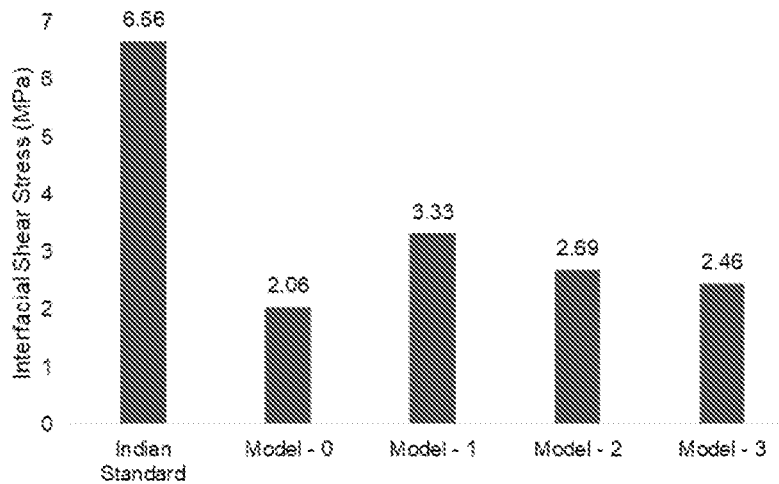


FIG. 12B

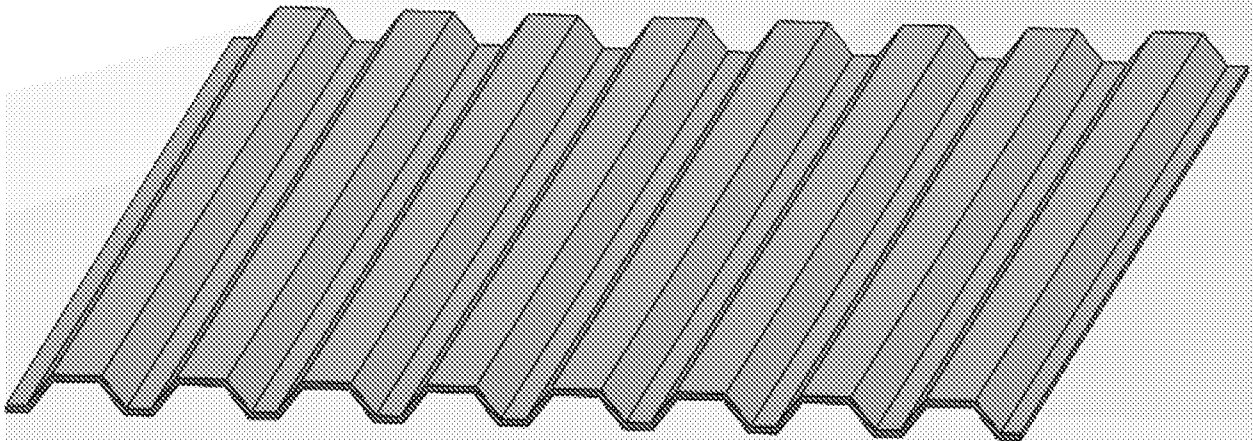


FIG. 13

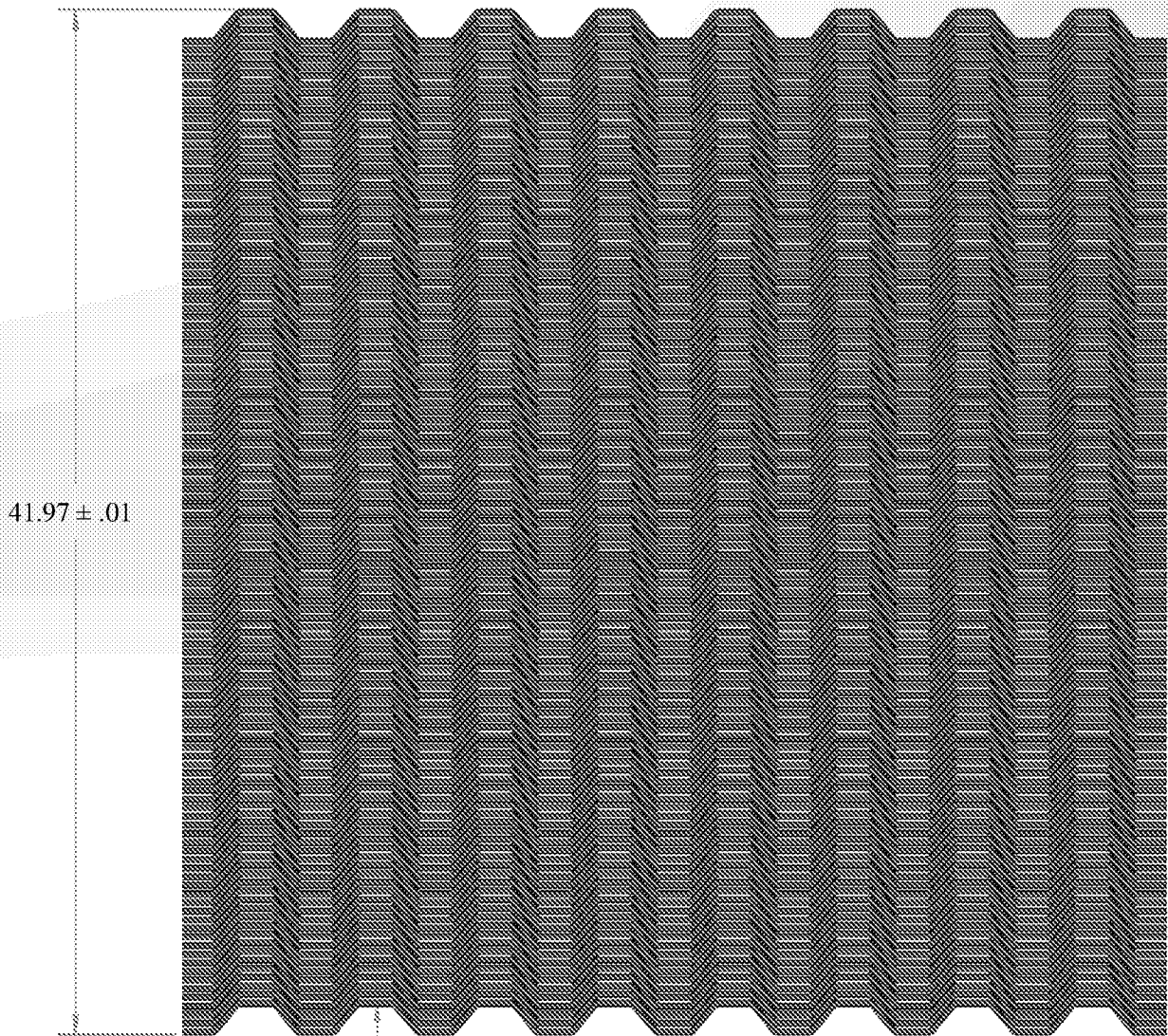


FIG. 14

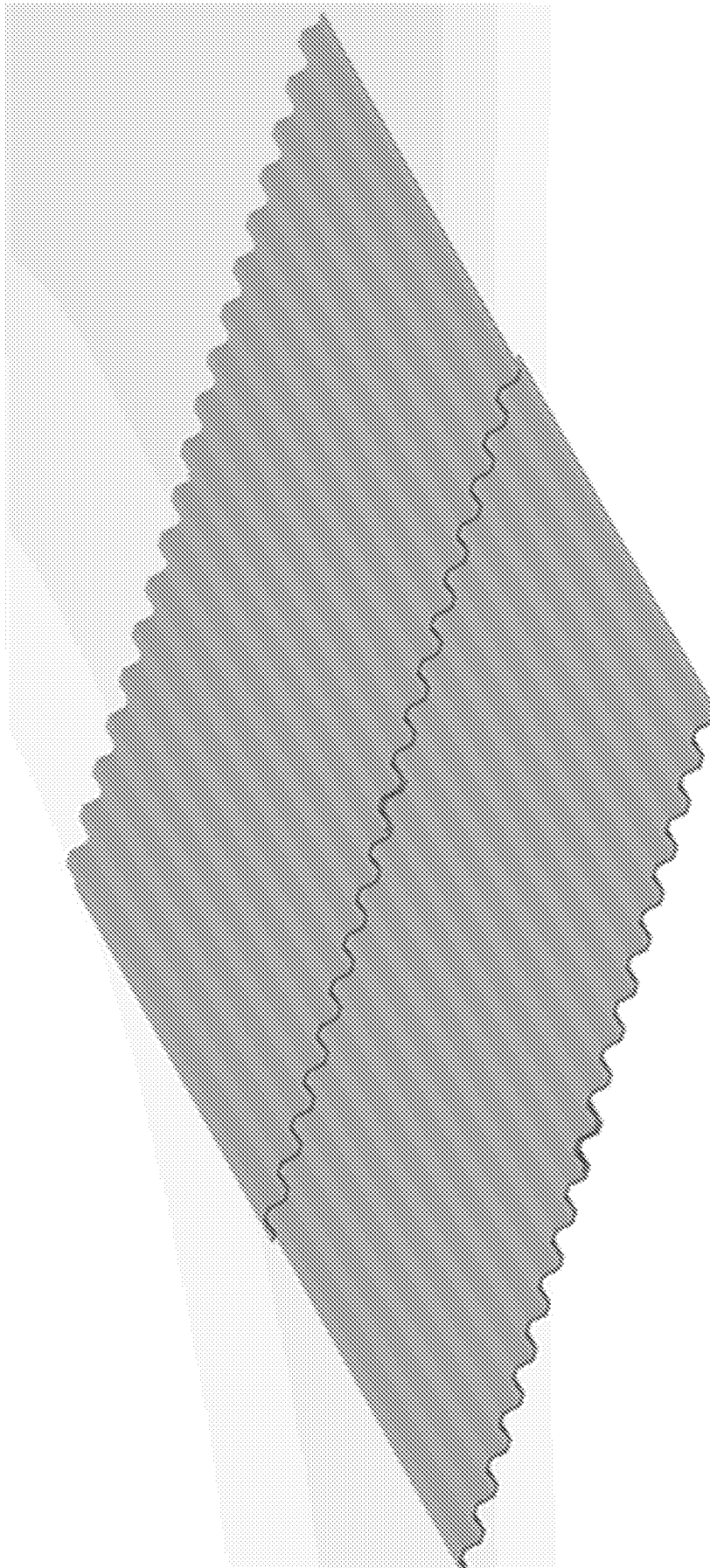


FIG. 15A

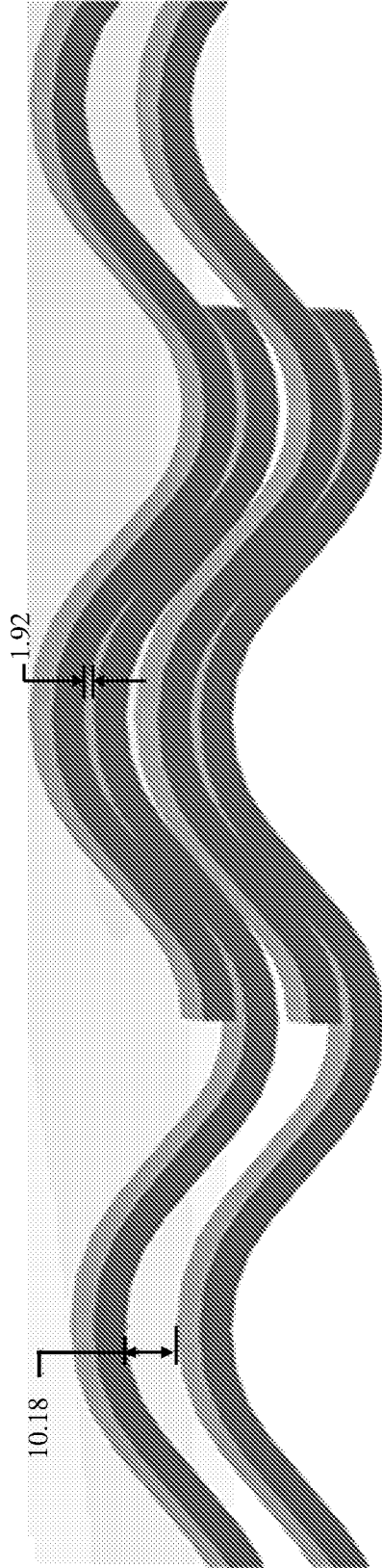


FIG. 15B

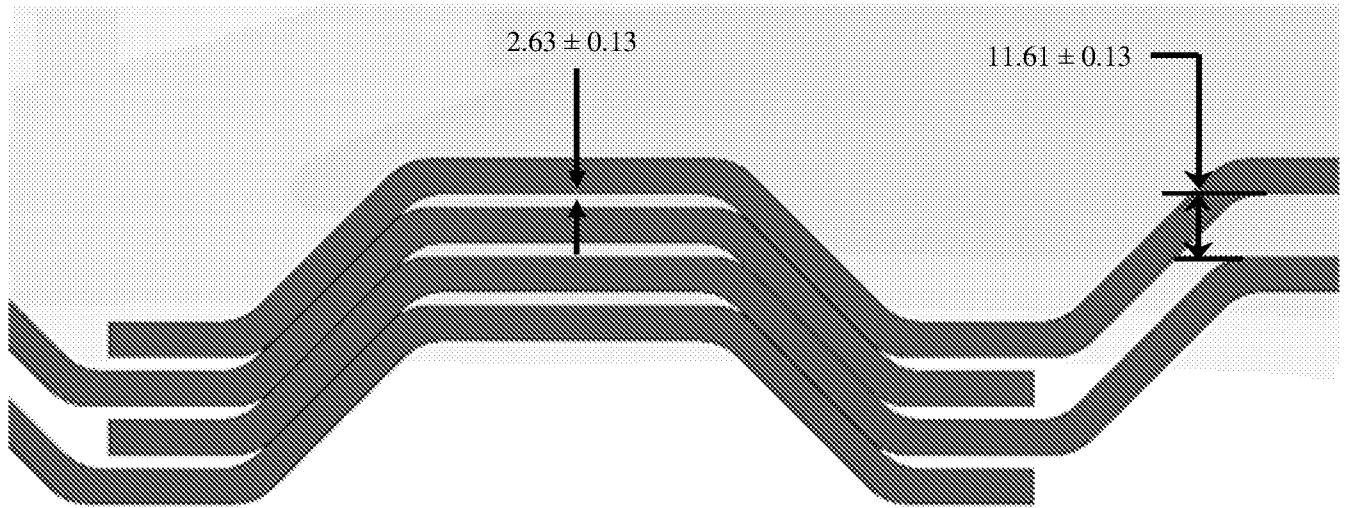


FIG. 15C

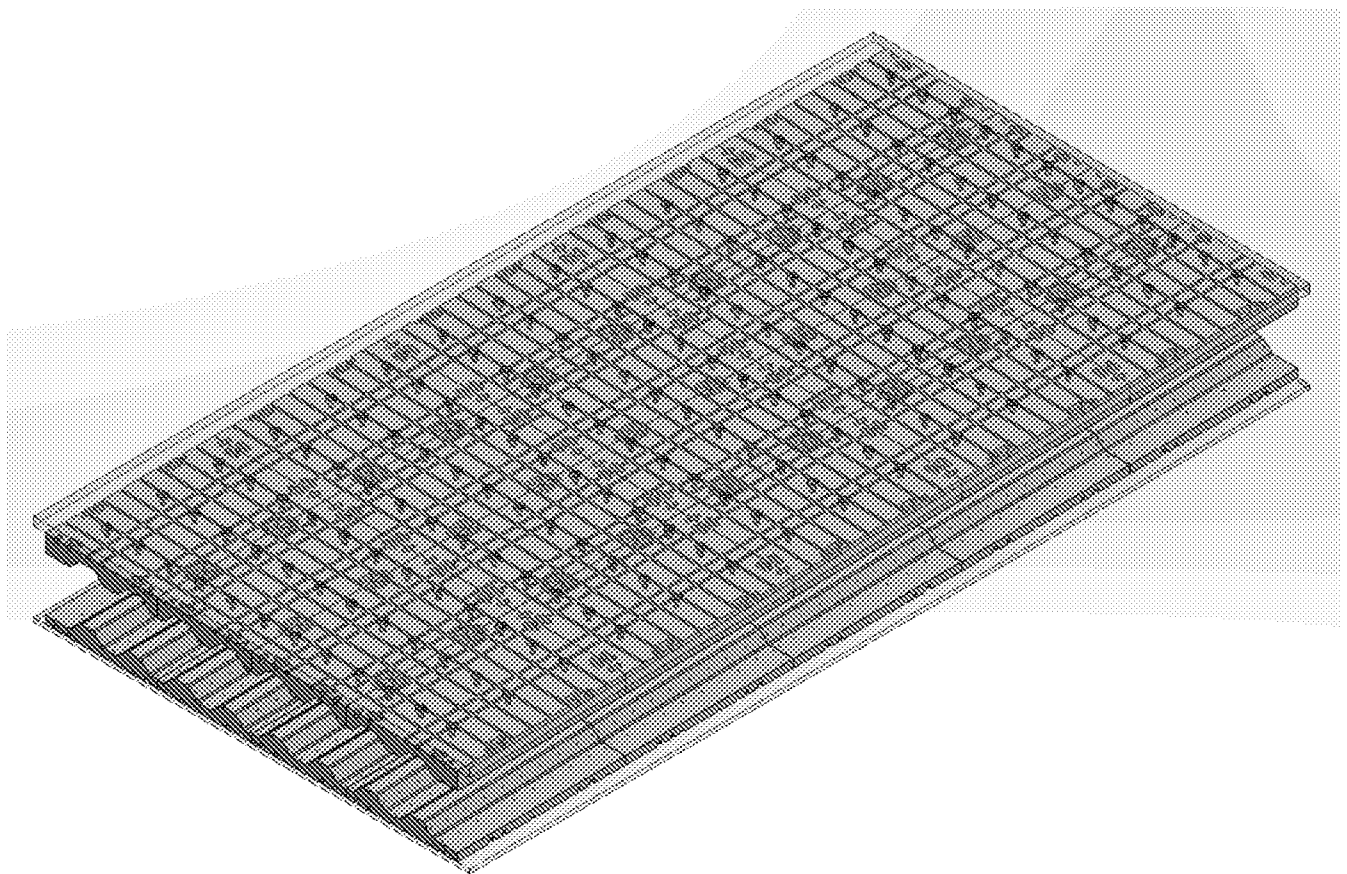


FIG. 16

INTERNATIONAL SEARCH REPORT

International application No PCT/US2024/054258

A. CLASSIFICATION OF SUBJECT MATTER
 INV. E04C2/16 B27N3/02 B27N3/04 E04C2/32 E04D3/32
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
 Minimum documentation searched (classification system followed by classification symbols)
E04C E04D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 8 475 894 B2 (NOBLE ROBERT [US]; HUNT JOHN F [US] ET AL.) 2 July 2013 (2013-07-02) the whole document -----	1 - 19
Y	DE 40 20 682 A1 (DARMA JOSEPH [DE]) 2 January 1992 (1992-01-02) the whole document -----	1 - 19
Y	EP 0 765 738 A1 (ONNETSU KANKYO KAIHATSU INC [JP]; TOA SHOJI CO LTD [JP]) 2 April 1997 (1997-04-02) page 2, line 5 - line 6 page 2, line 37 - line 57 page 6, line 9 - line 13 page 6, line 42 - line 51; figure 1 ----- -/-	1 - 19

Further documents are listed in the continuation of Box C. See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
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Date of the actual completion of the international search 4 February 2025	Date of mailing of the international search report 19/03/2025
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Giannakou, Evangelia
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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/054258

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2024/054258

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