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(54) **CONNECTION SURFACE FOR A STRUCTURAL UNIT**

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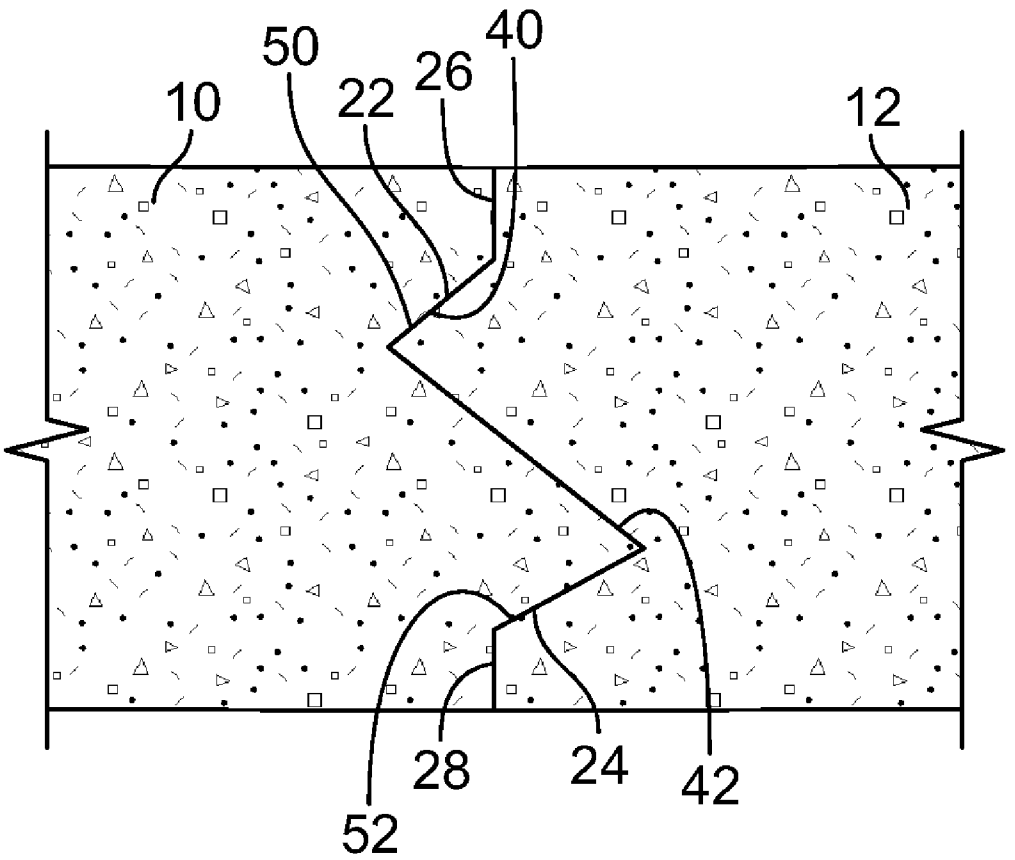
(57) **ABSTRACT**

A connection surface that is disposed on at least a portion of a face of a structural unit comprises a first convex surface and a first concave surface arranged substantially along a first line. The shape of the first concave surface is complementary to the shape of the first convex surface. A second convex surface and a second concave surface are arranged substantially along a second line that is substantially parallel to the first line. The shape of the second concave surface is complementary to the shape of the second convex surface. The concave-convex order of the second line is reversed relative to the first line, such that the second convex surface corresponds with the first concave surface and the second concave surface corresponds with the first convex surface.



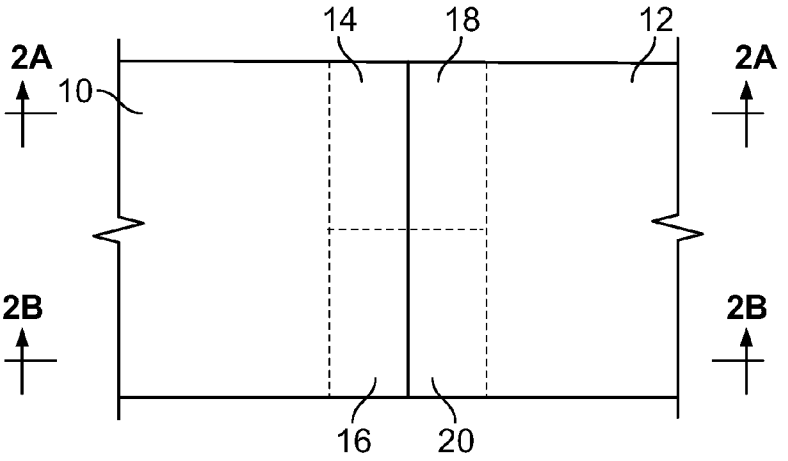


FIG. 1

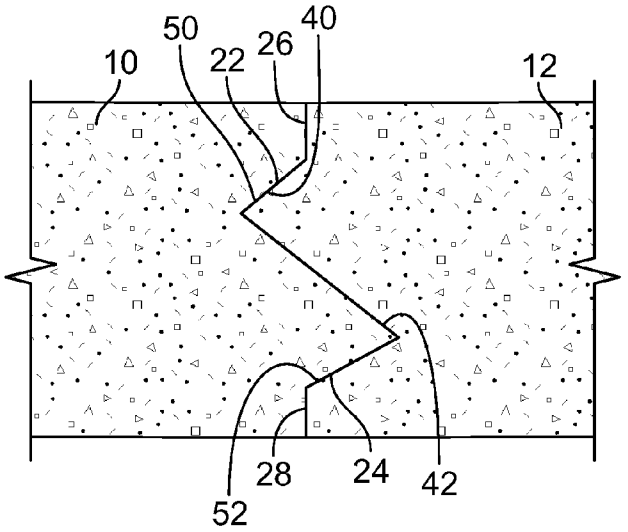


FIG. 2A

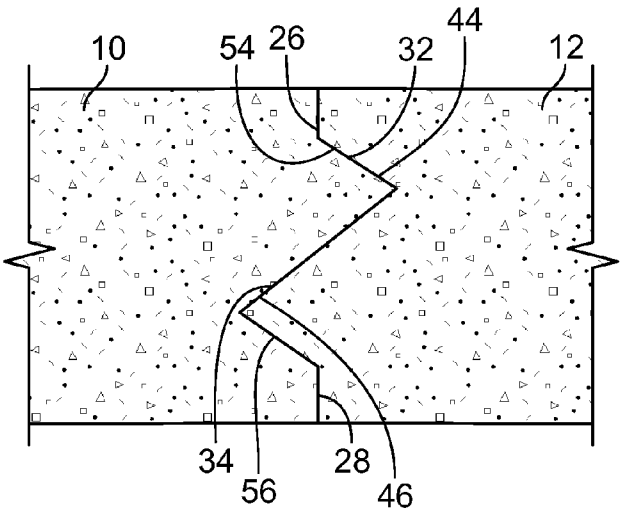


FIG. 2B

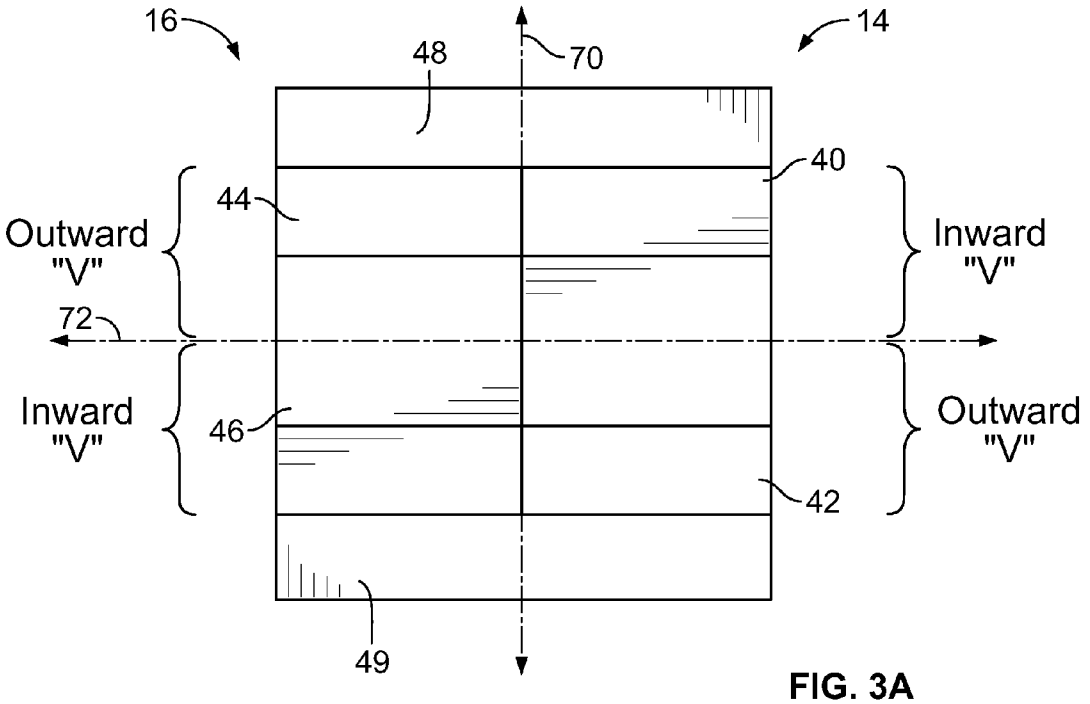
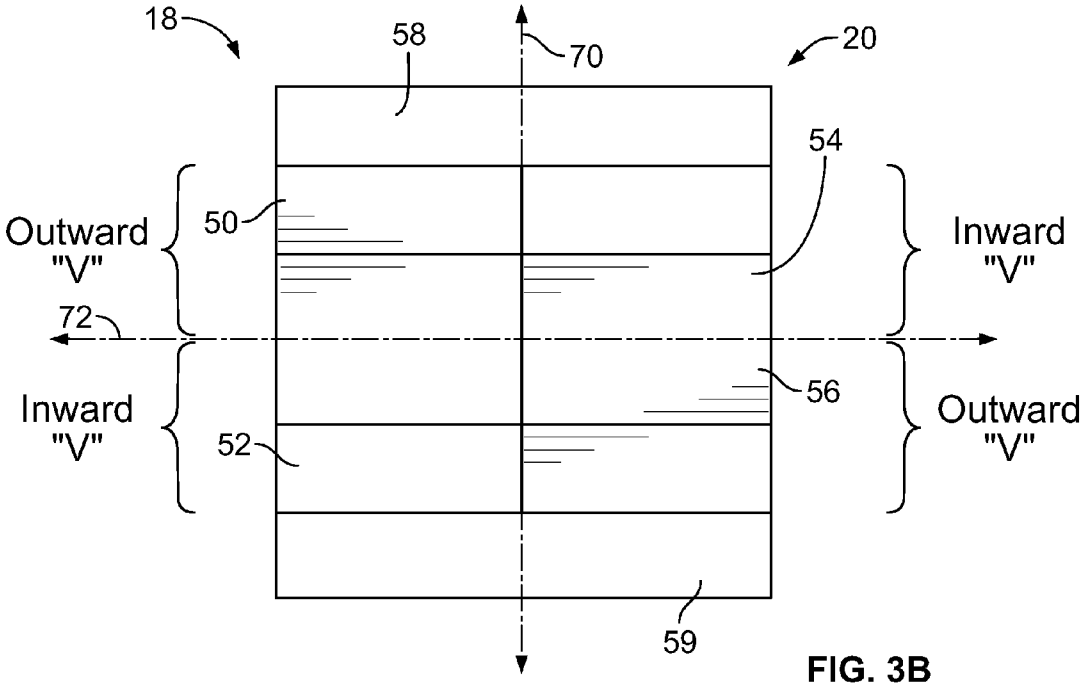

16
14
48
70
40
44
Outward "V"
Inward "V"
72
Inward "V"
46
Outward "V"
42
49

FIG. 3A


18
58
70
20
54
Outward "V"
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Inward "V"
72
Inward "V"
56
Outward "V"
52
59

FIG. 3B

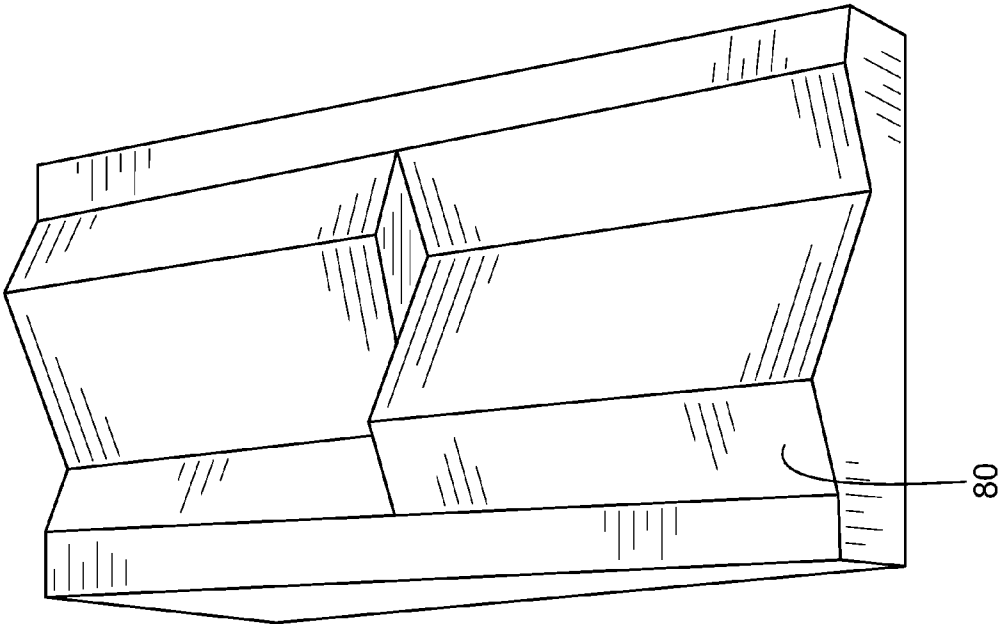

FIG. 5

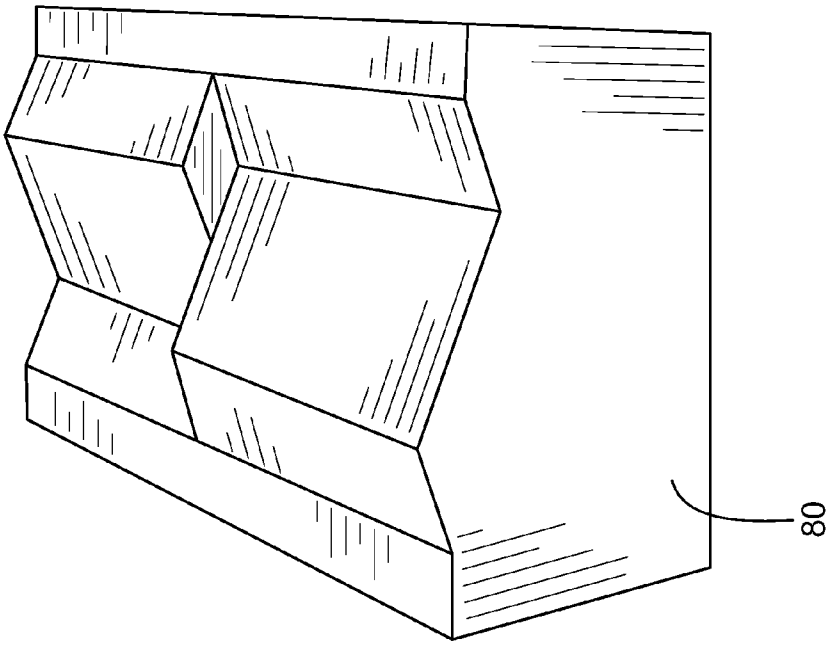

FIG. 4

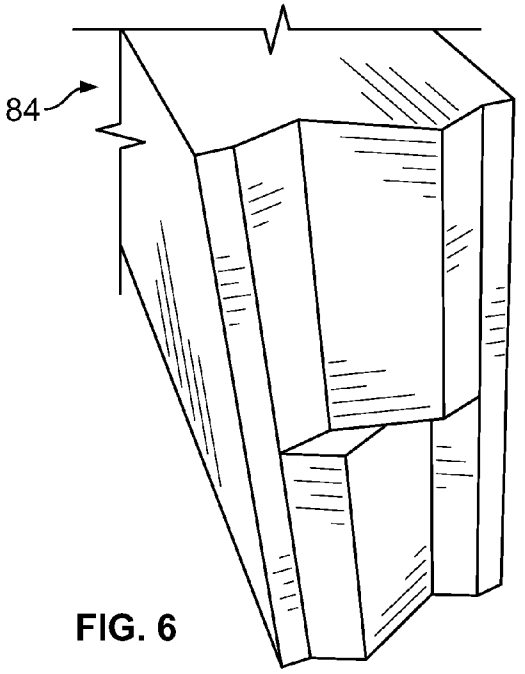

FIG. 6

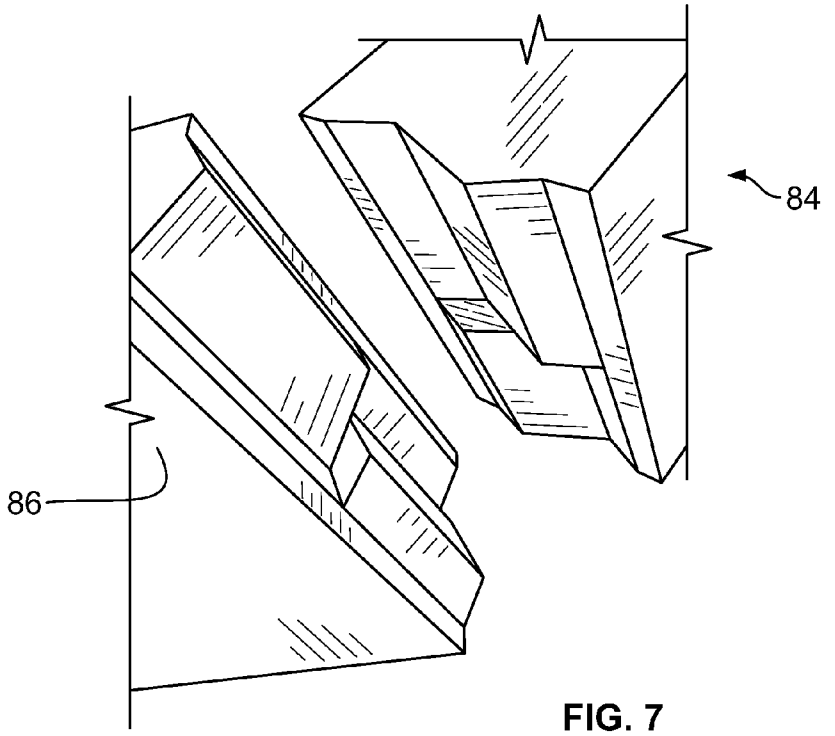

FIG. 7

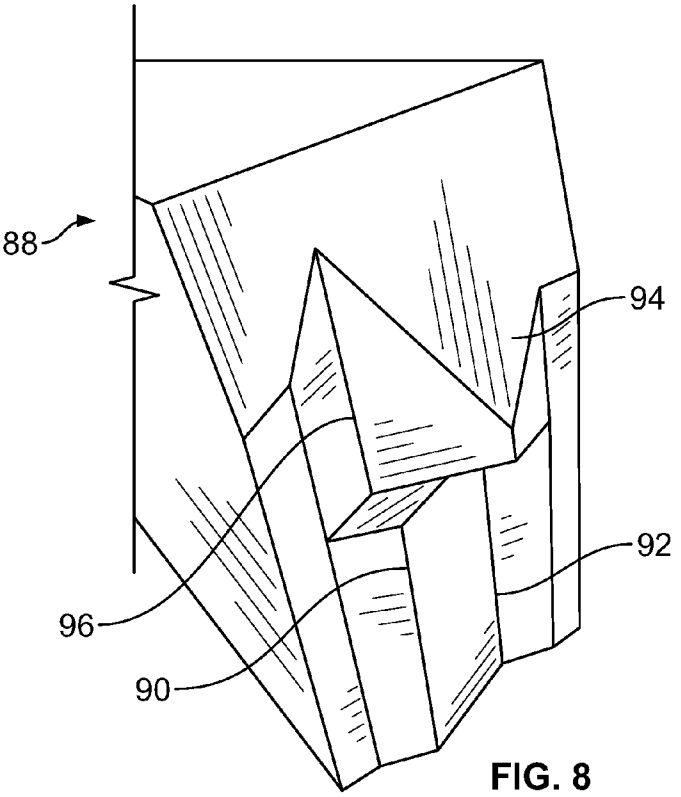

FIG. 8

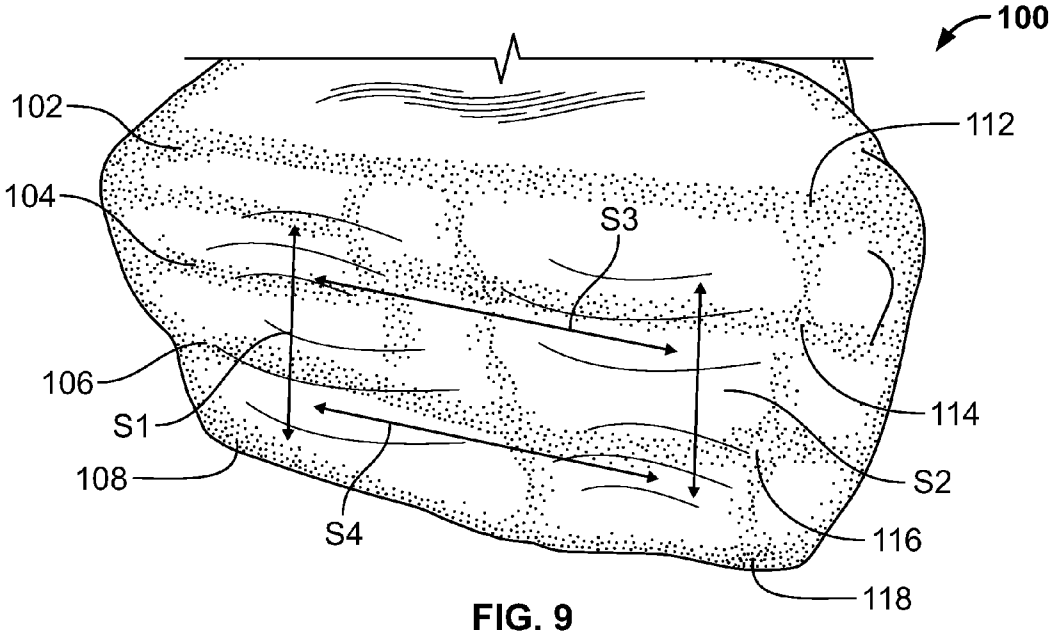

FIG. 9

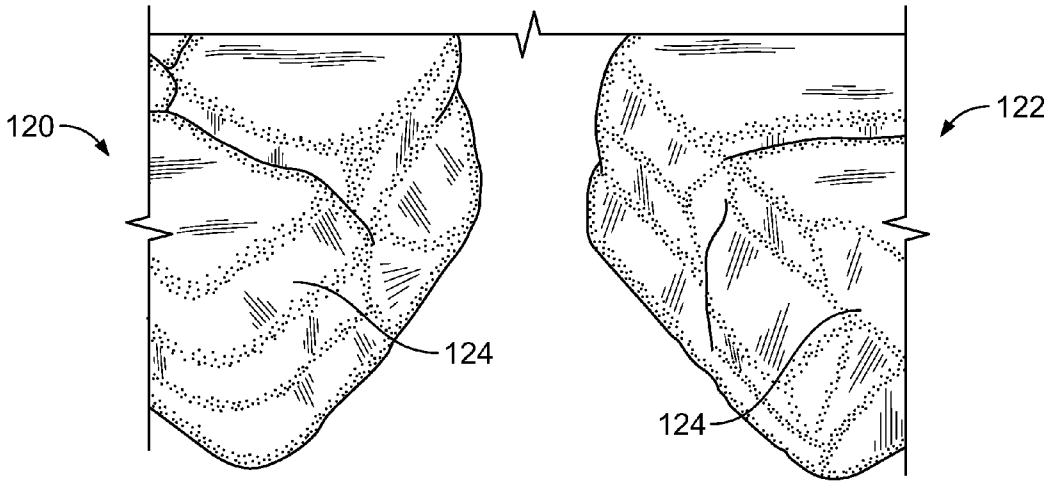

FIG. 10

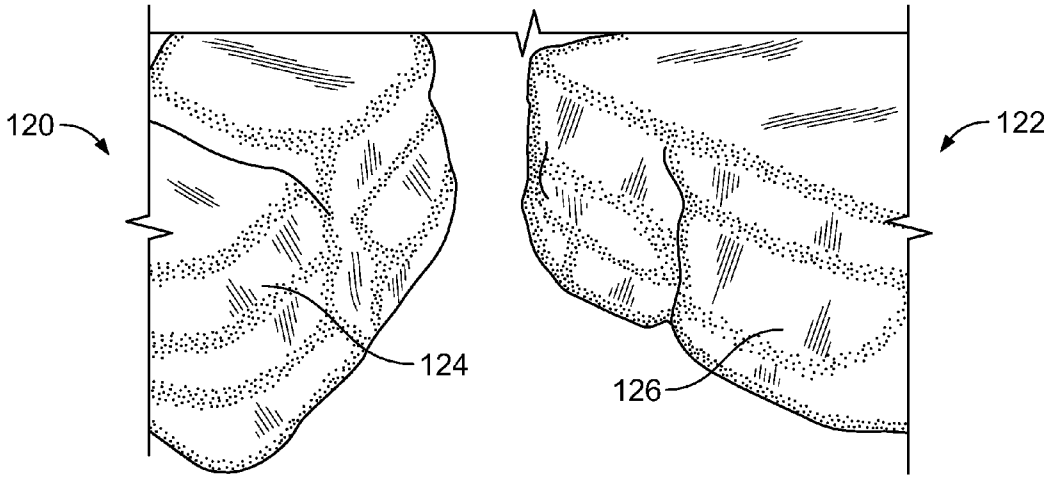

FIG. 11

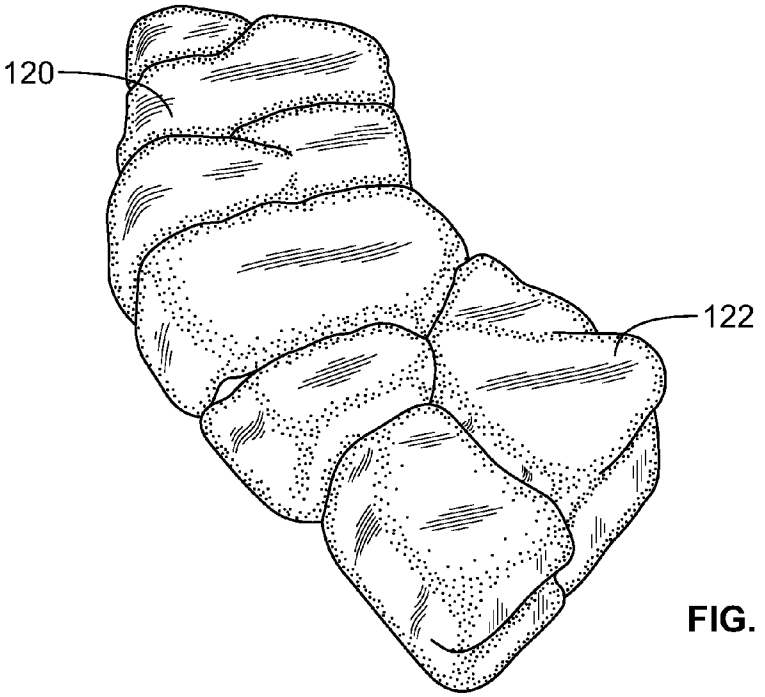

FIG. 12

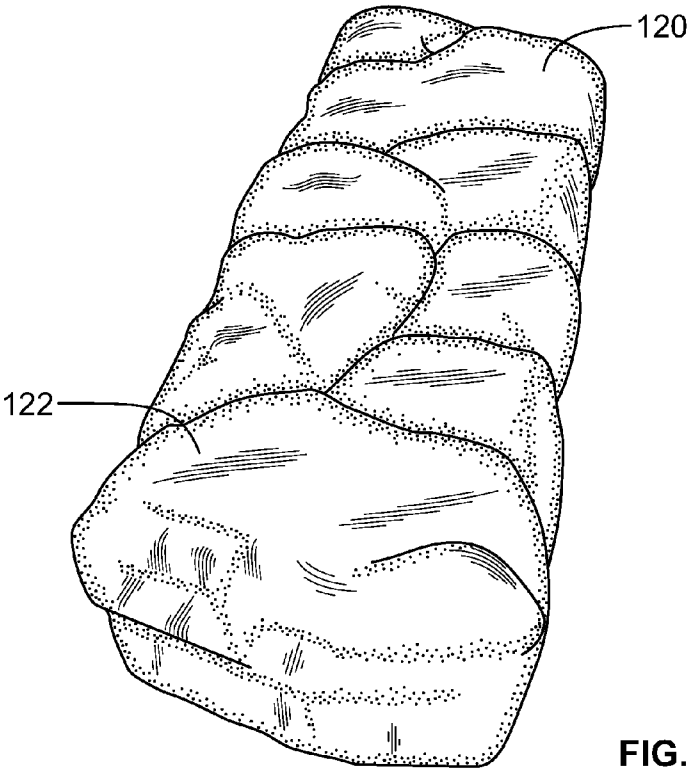

FIG. 13

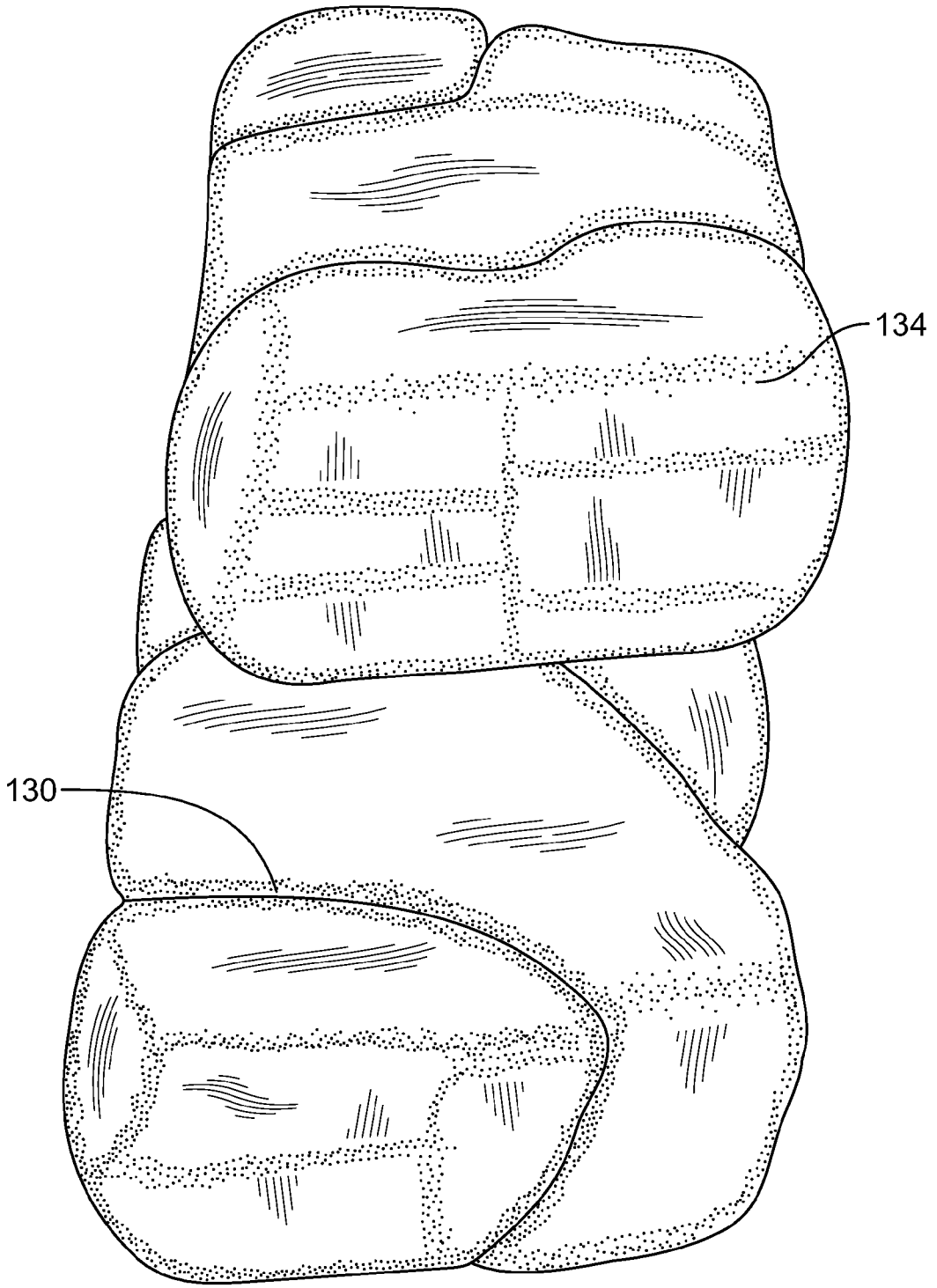

FIG. 14

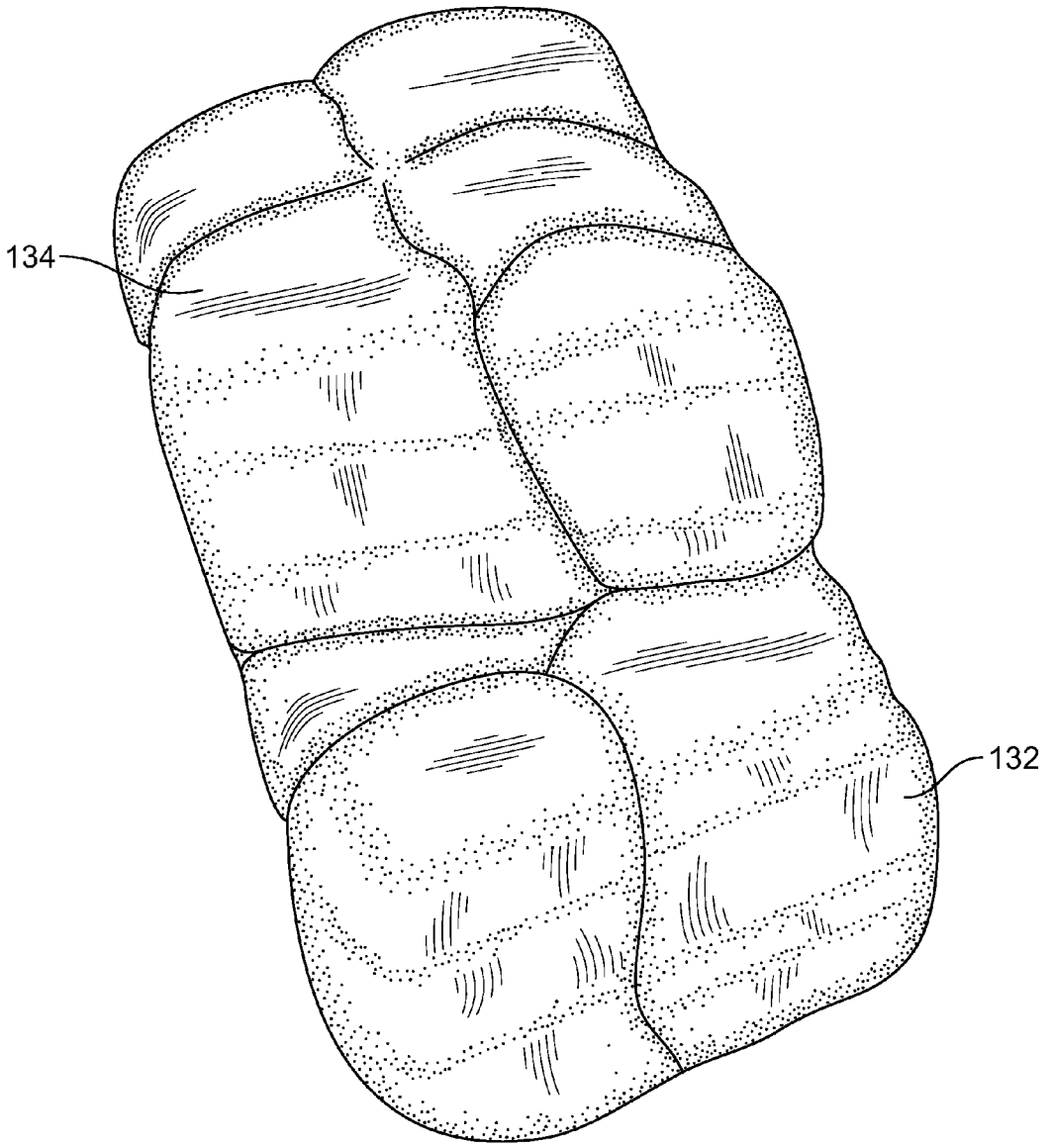

FIG. 15

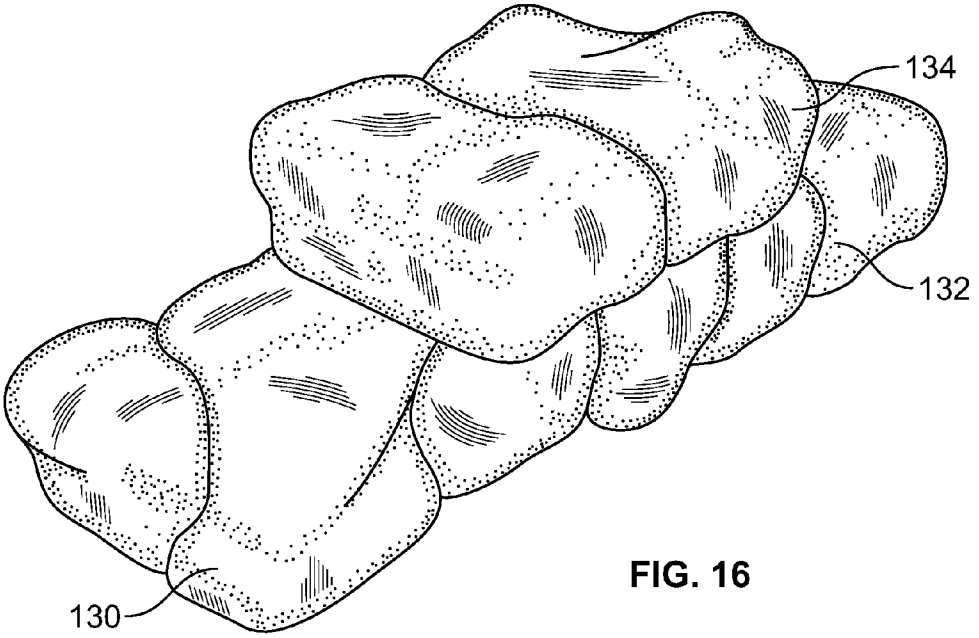

FIG. 16

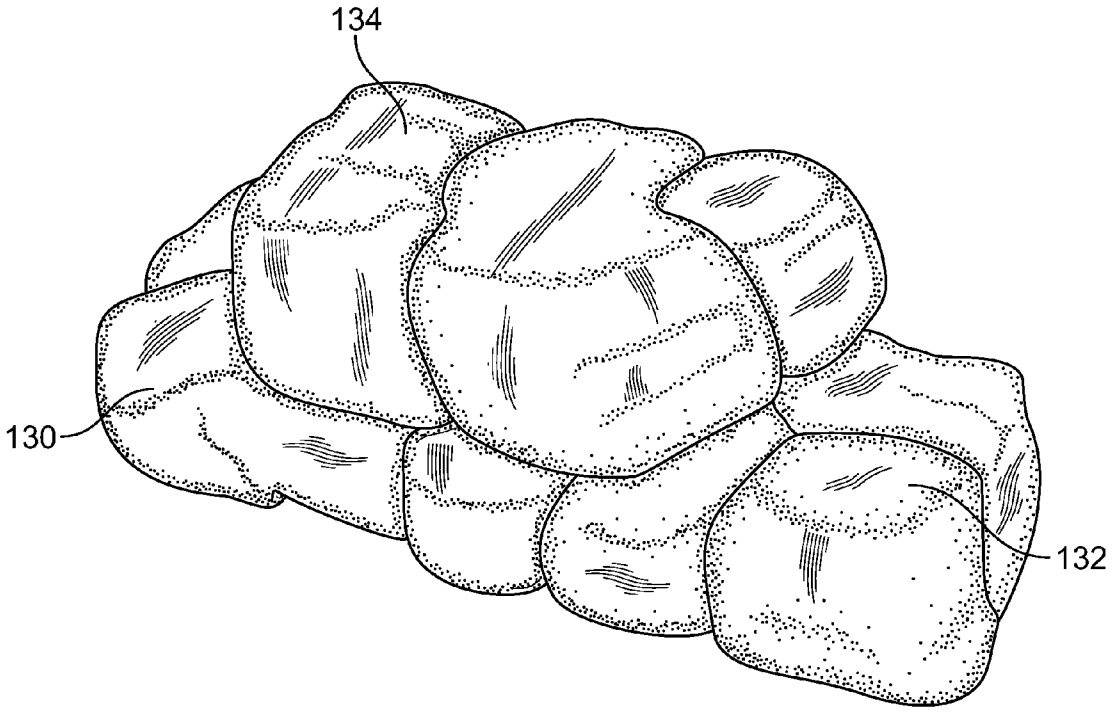

FIG. 17

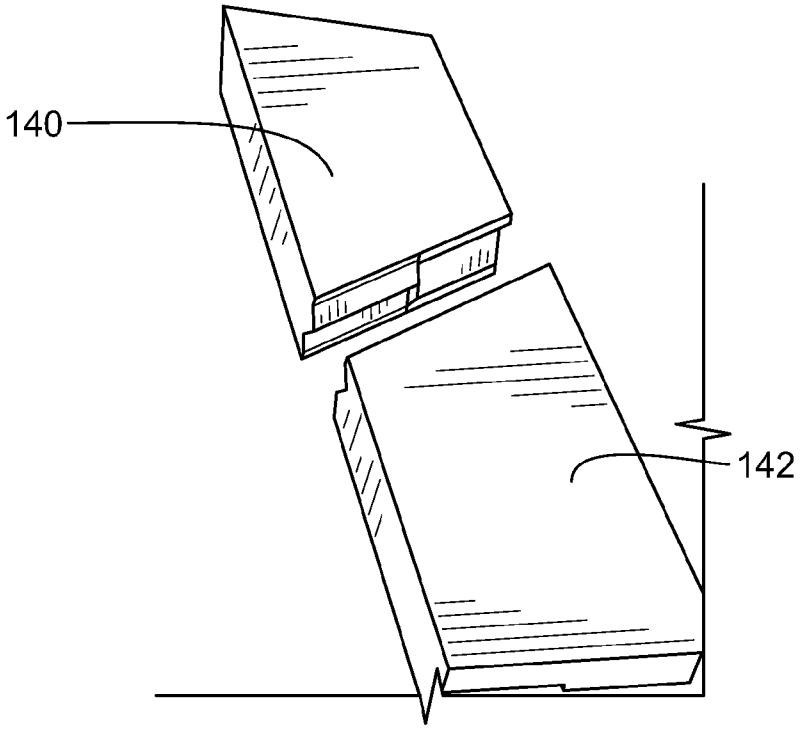

FIG. 18

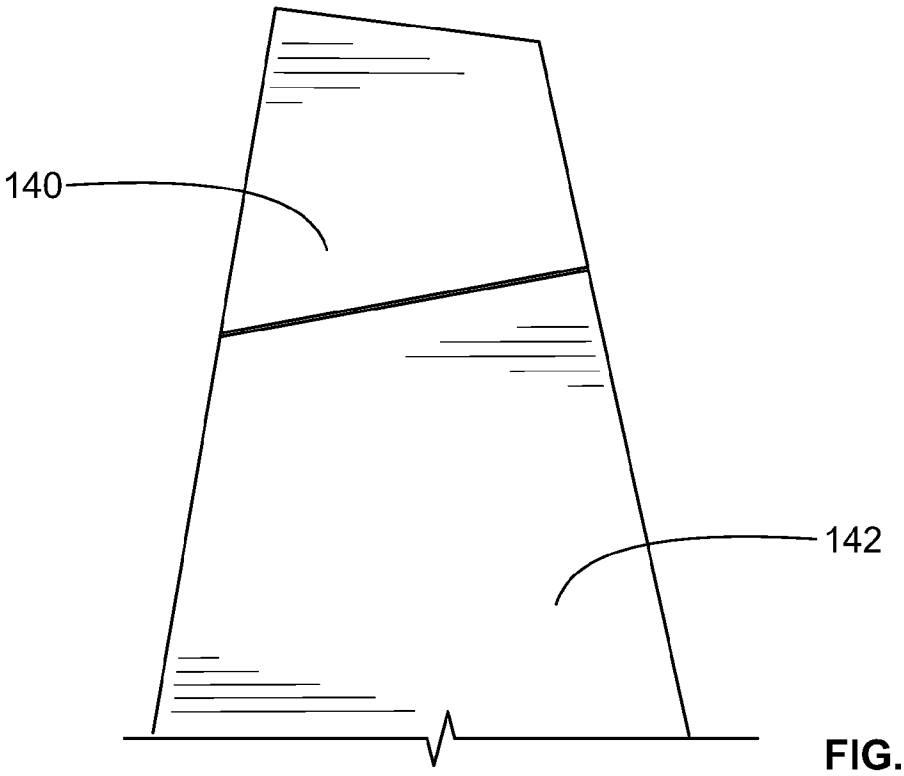

FIG. 19

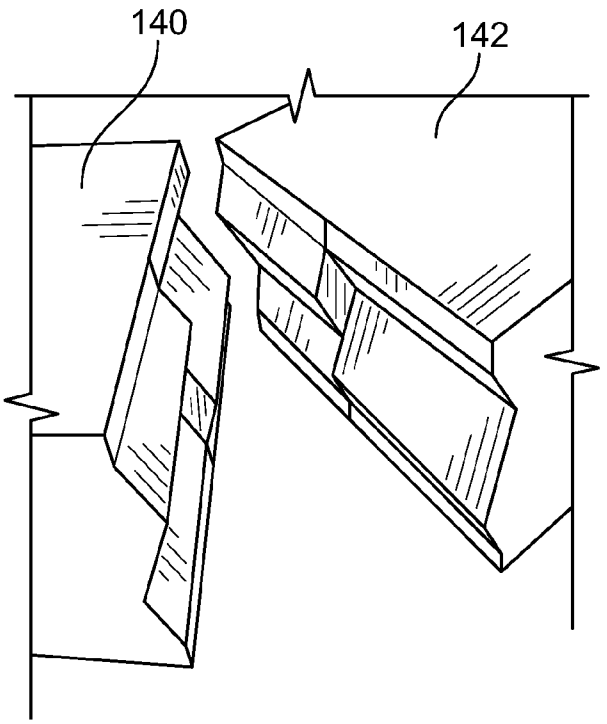

FIG. 20

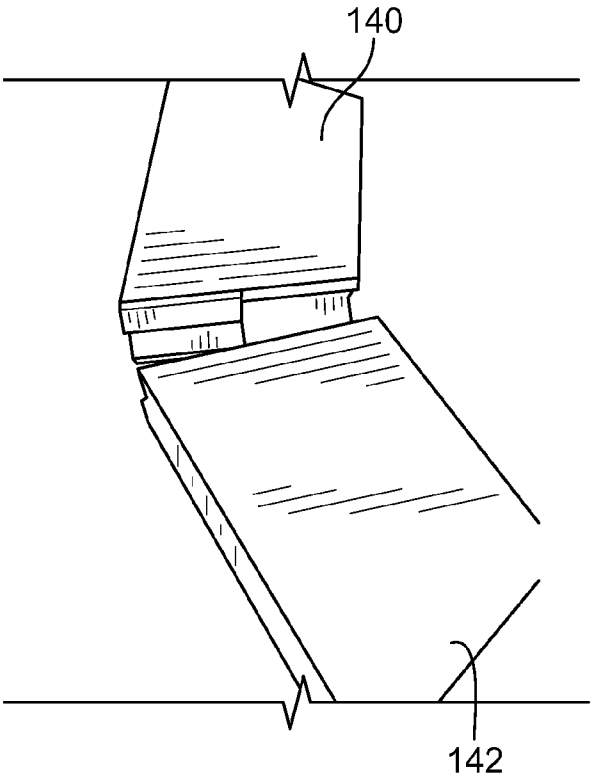

FIG. 21

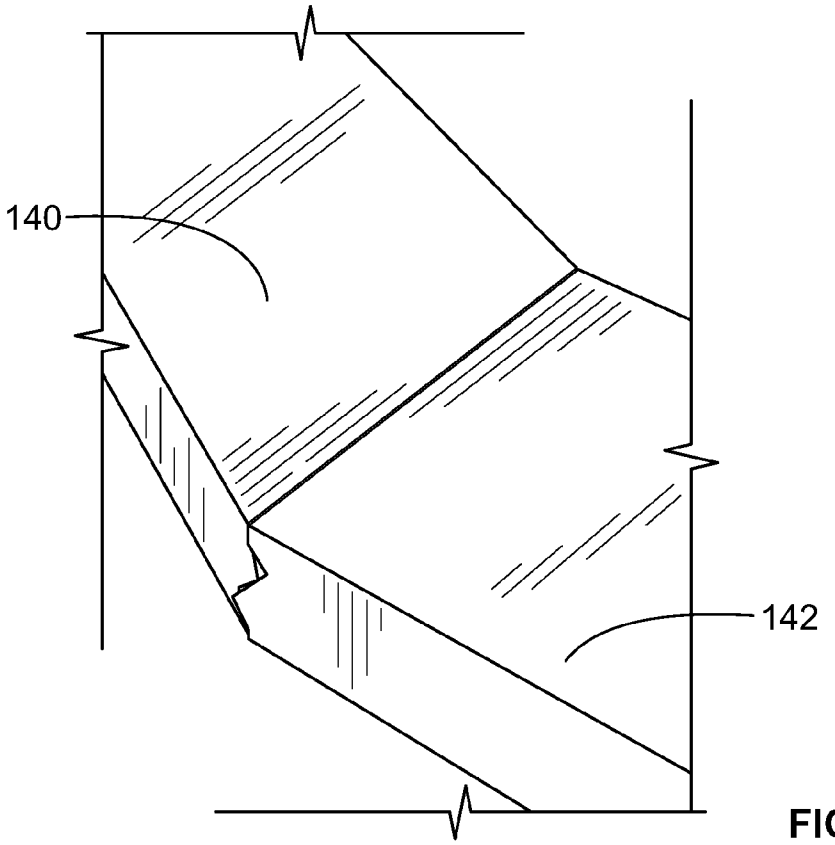

FIG. 22

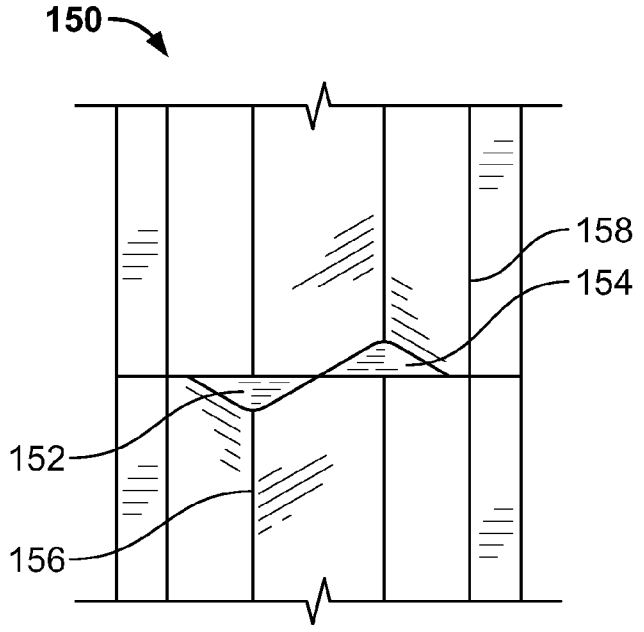

FIG. 23A

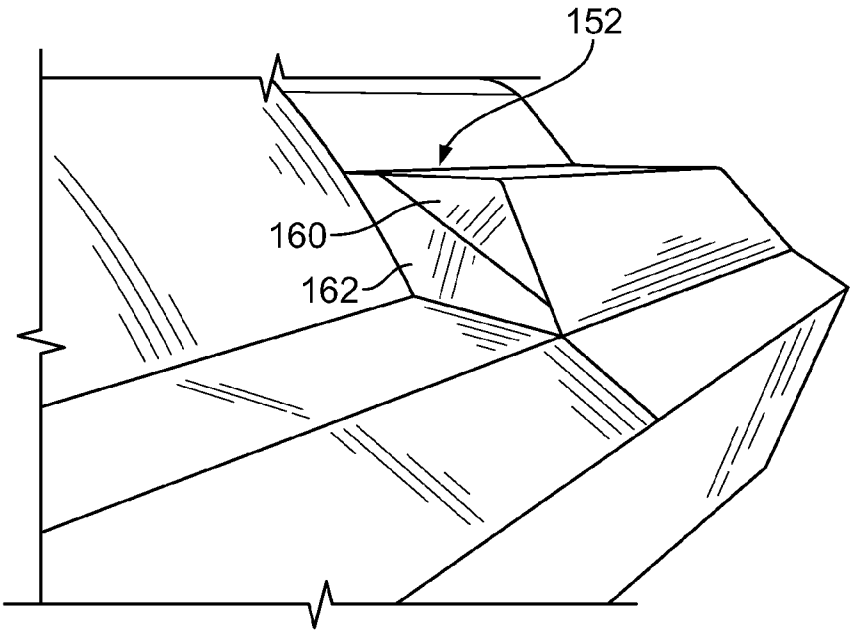

FIG. 23B

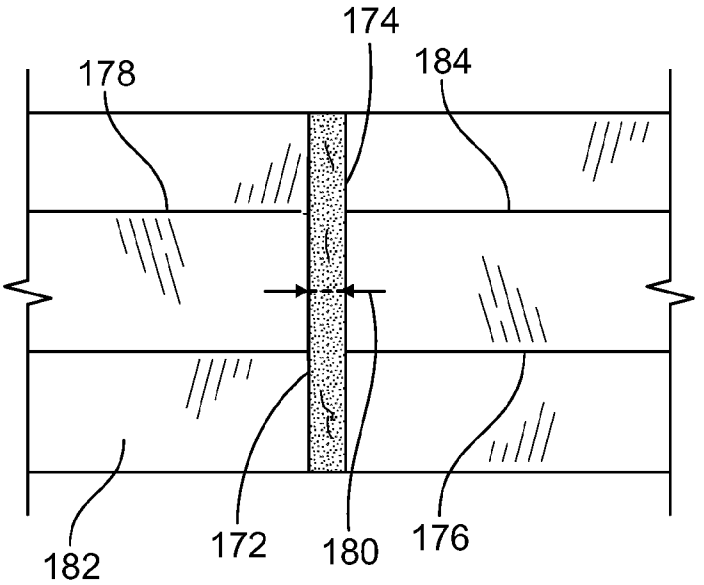

FIG. 24A

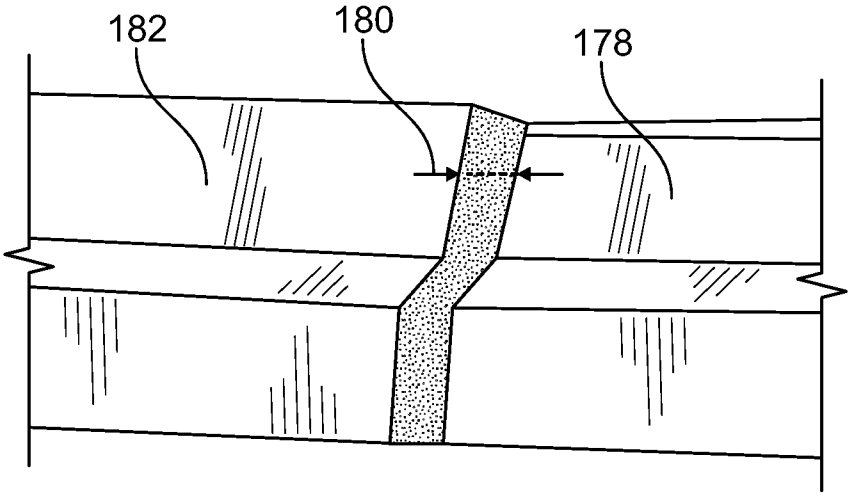

FIG. 24B

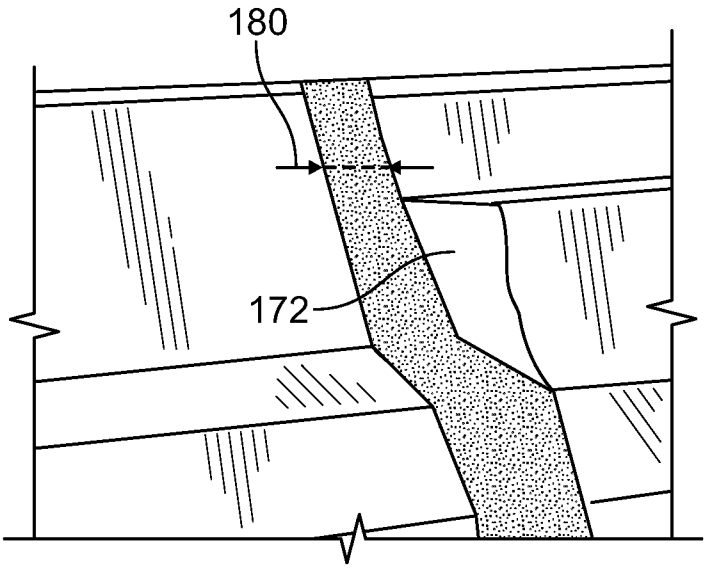

FIG. 24C

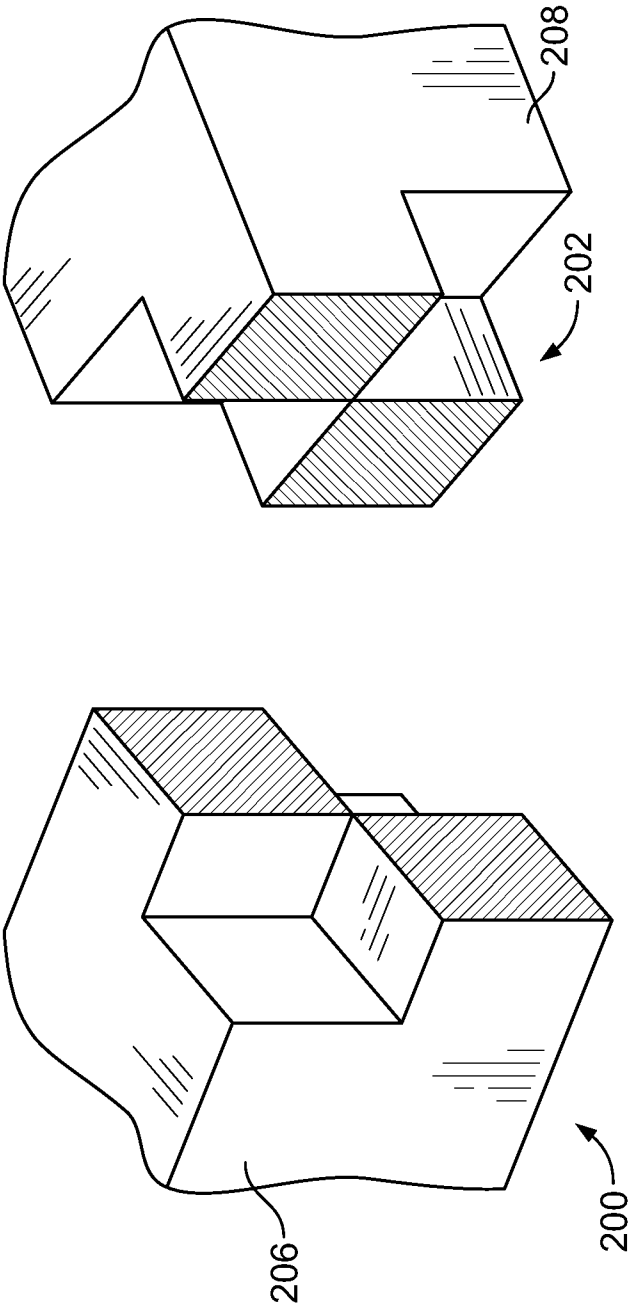

FIG. 25

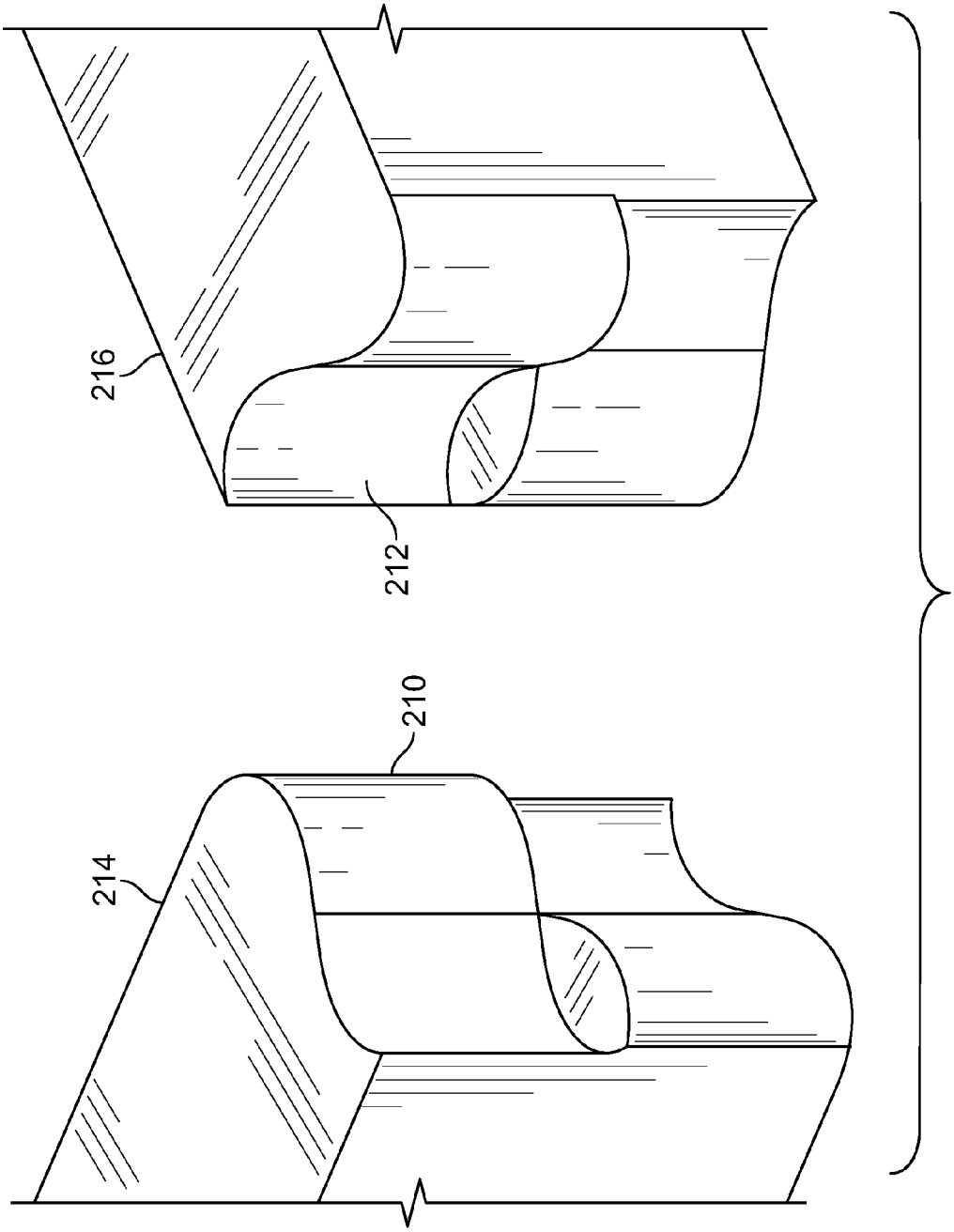

FIG. 26

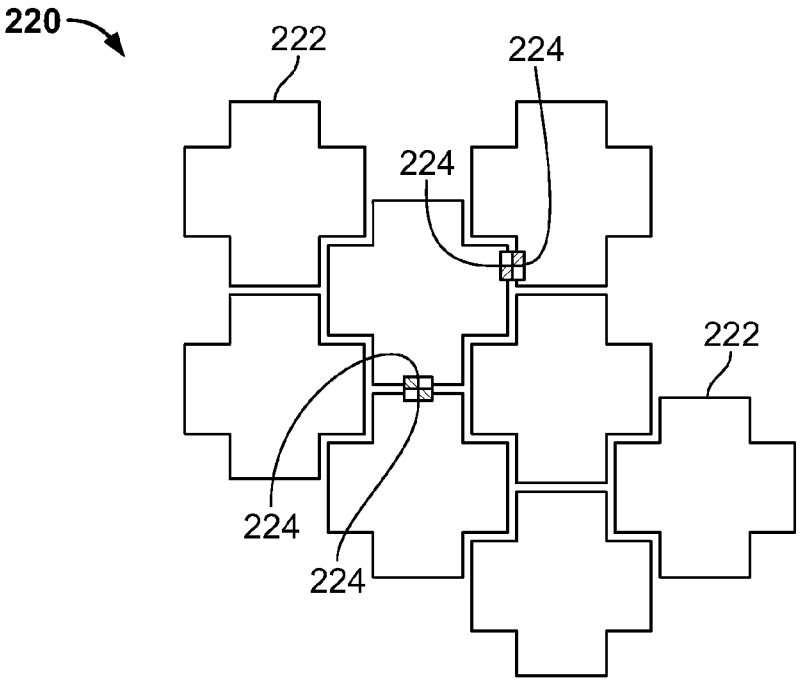

FIG. 27

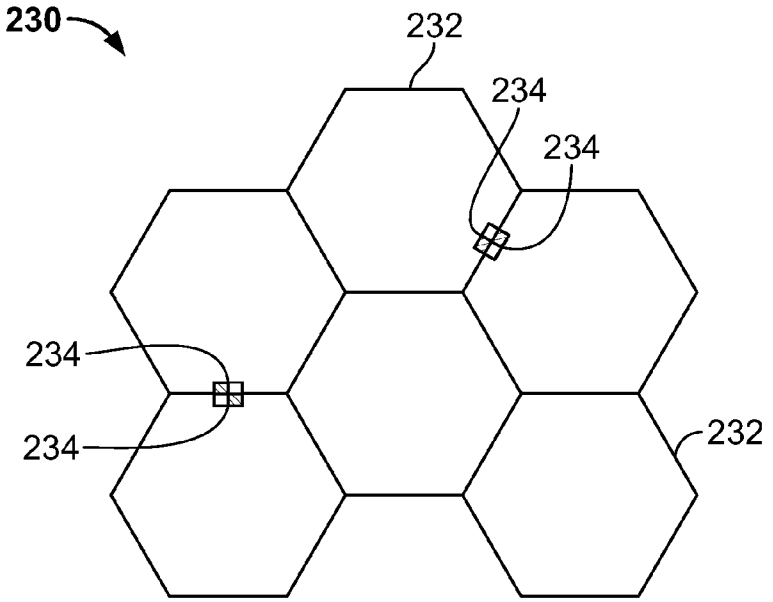

FIG. 28

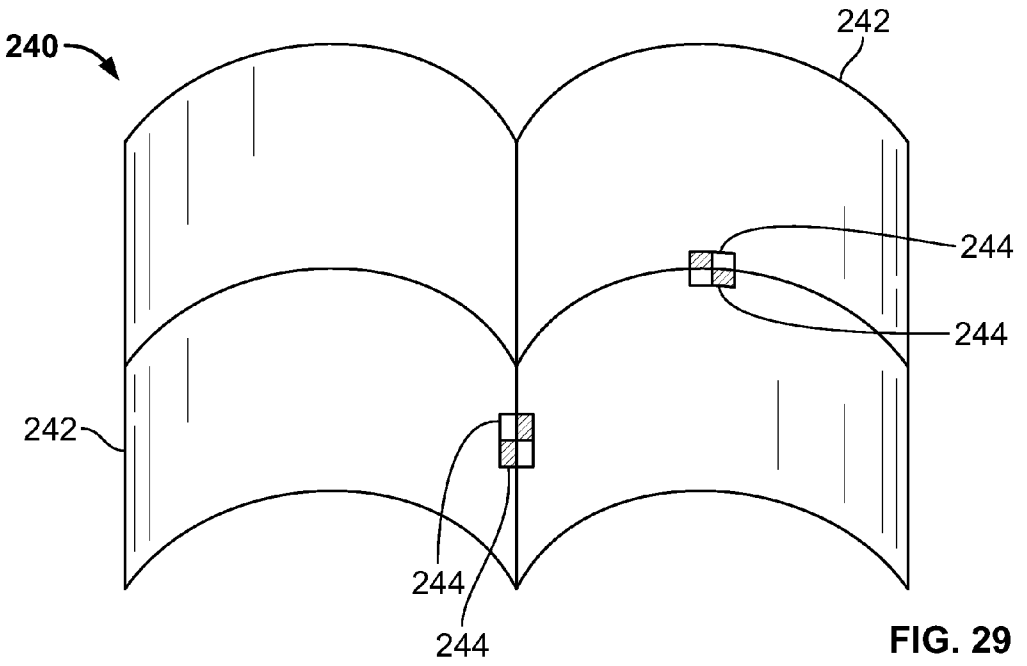

FIG. 29

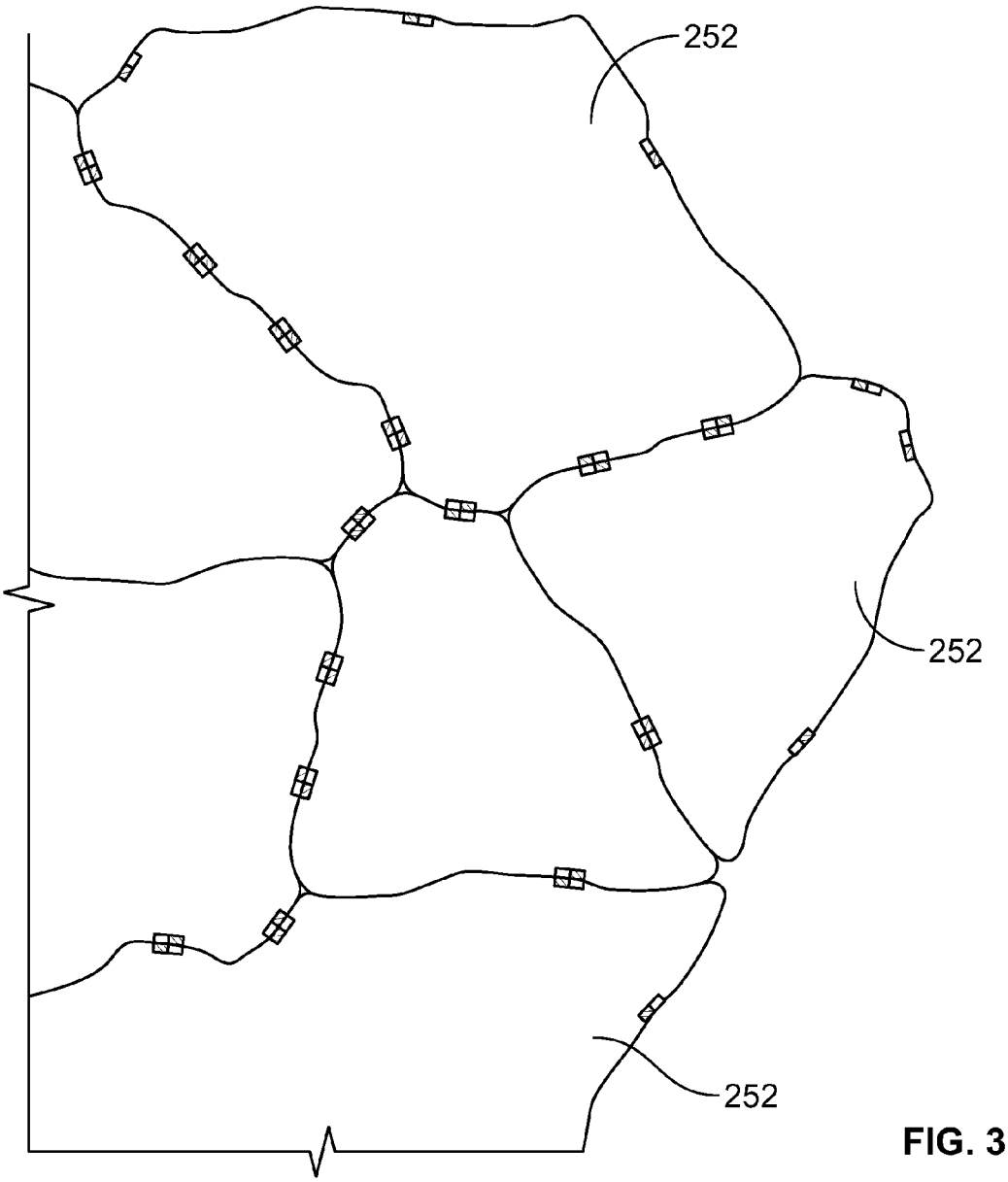

FIG. 30

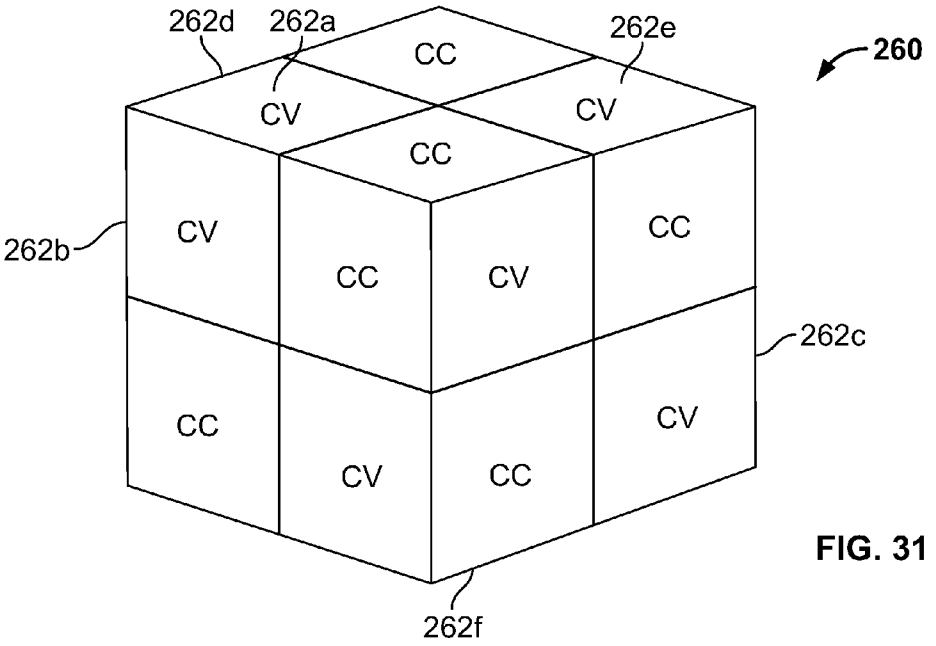
262d
262a
262e
260
CC
CV
CV
CC
262b
CV
CC
CV
CC
CC
CV
CC
CV
262c
CC
CV
CC
CV
262f

FIG. 31

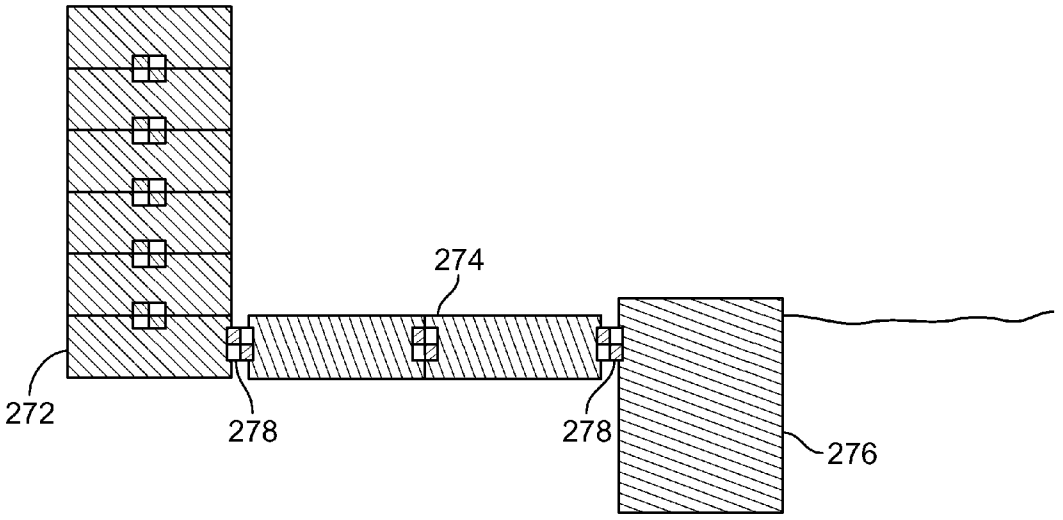
274
272
278
278
276

FIG. 32

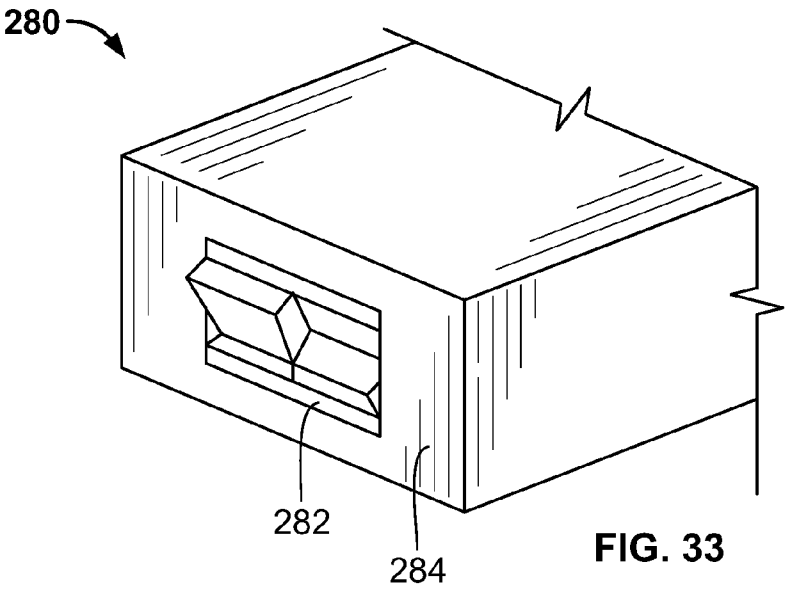

FIG. 33

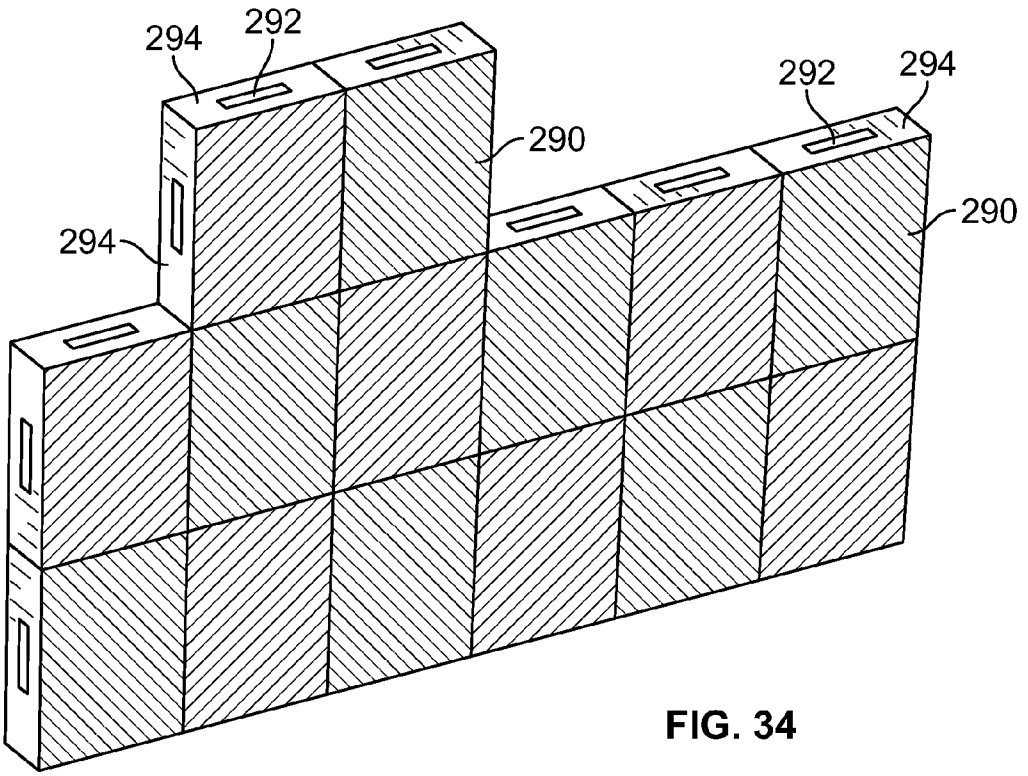

FIG. 34

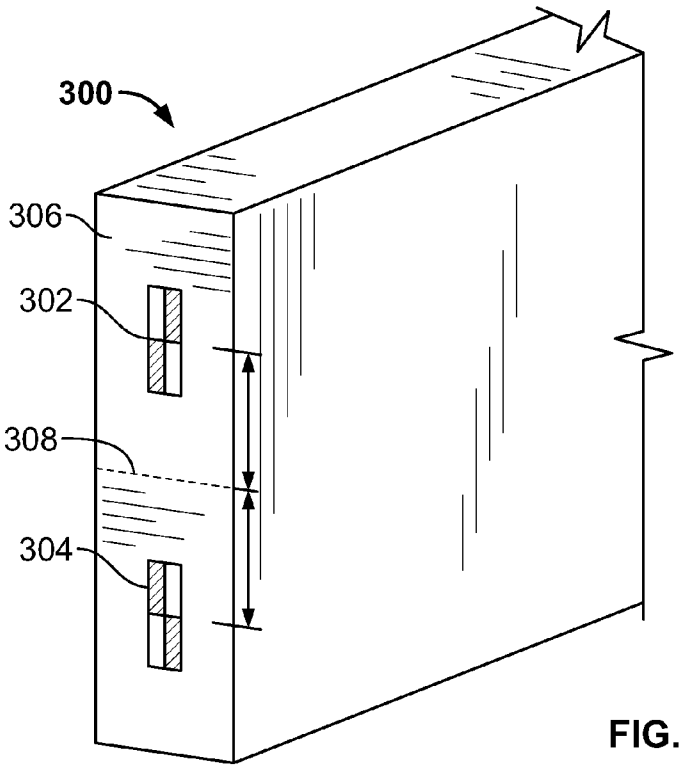

FIG. 35

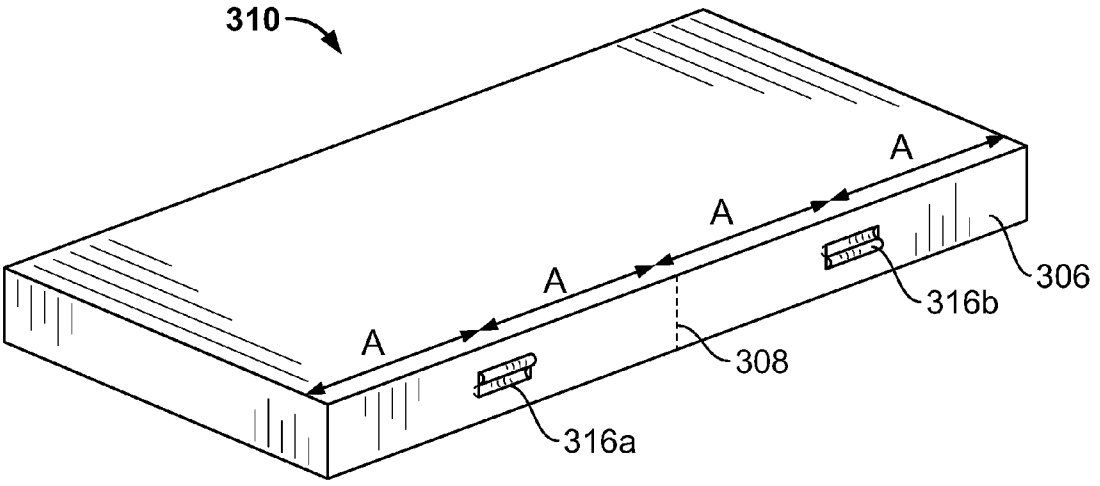

FIG. 36

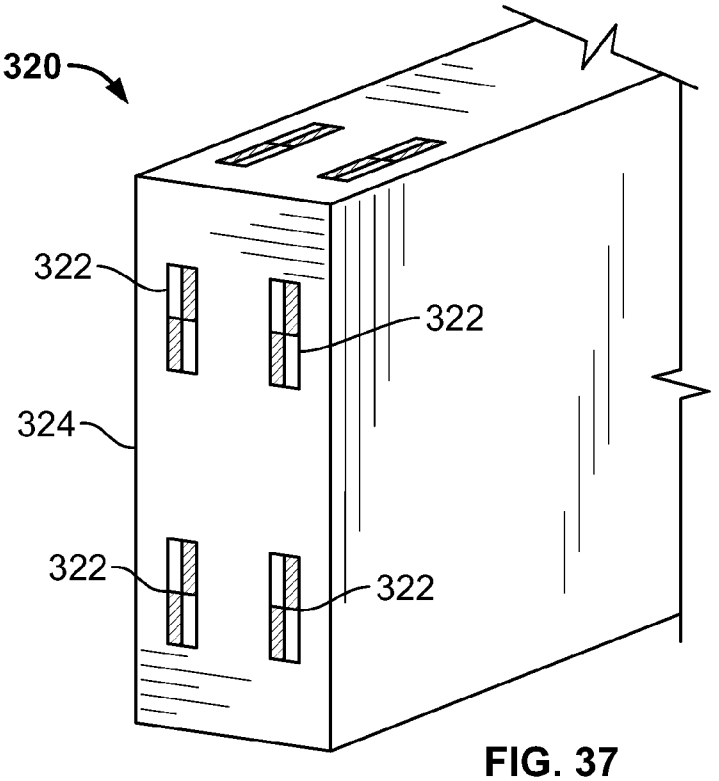

FIG. 37

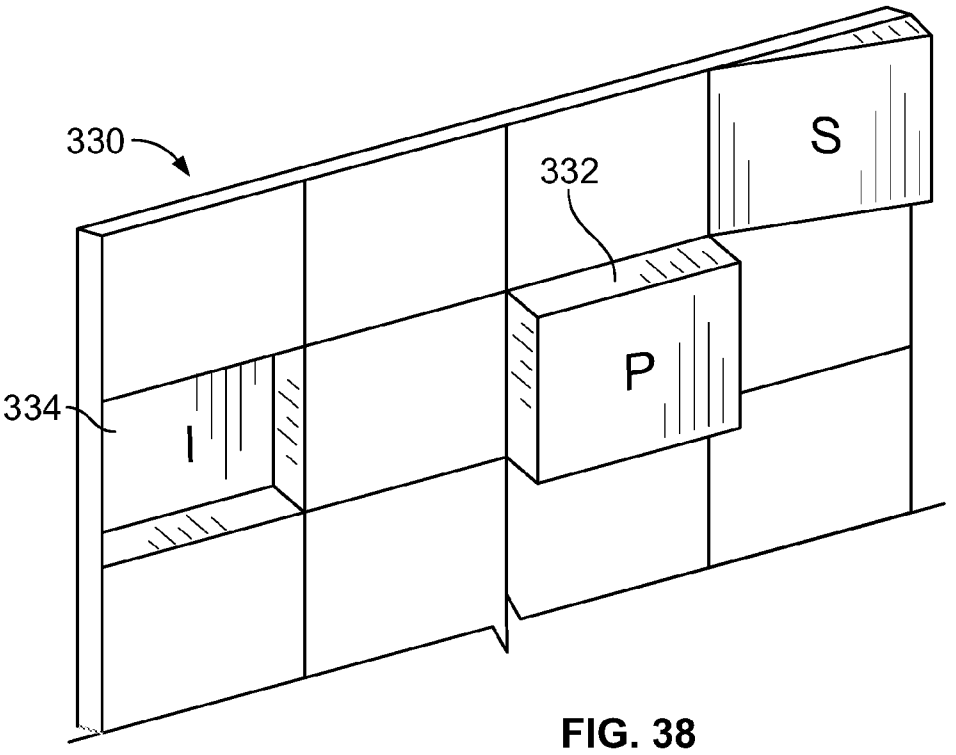

FIG. 38

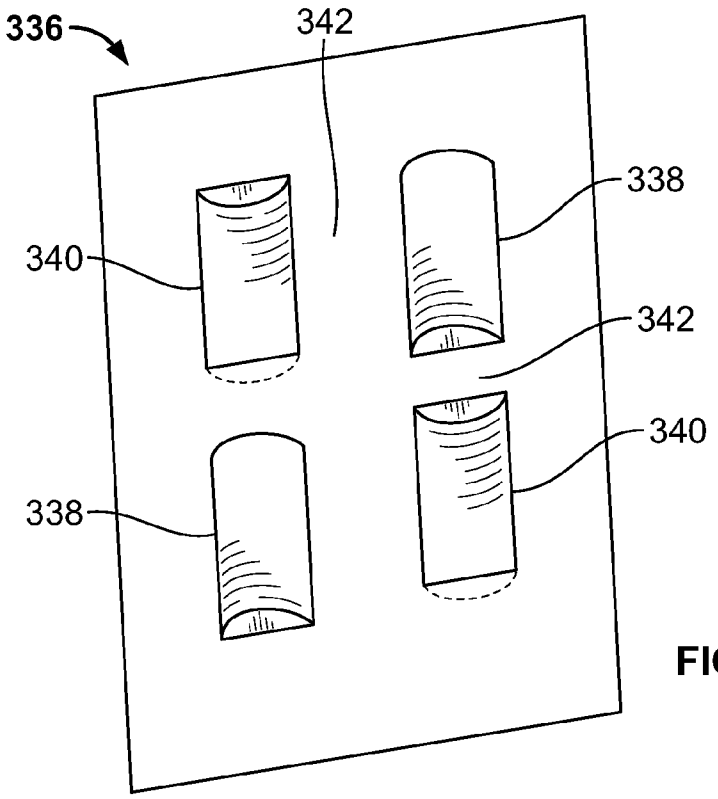

FIG. 39

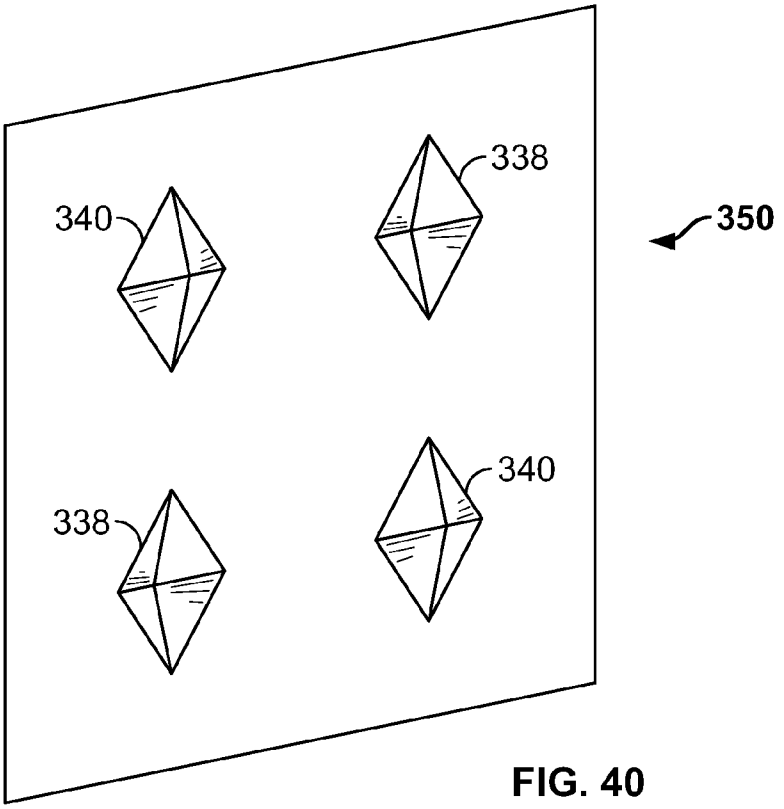

FIG. 40

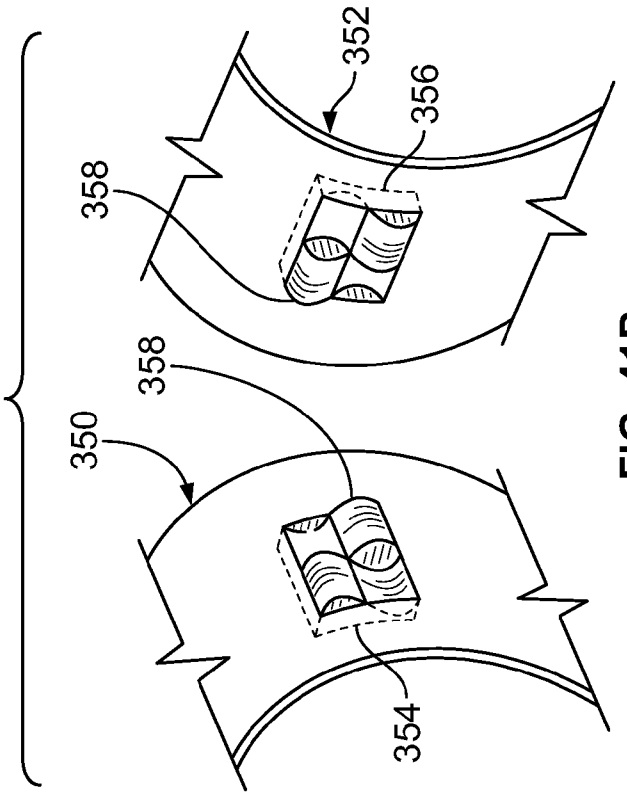

FIG. 41B

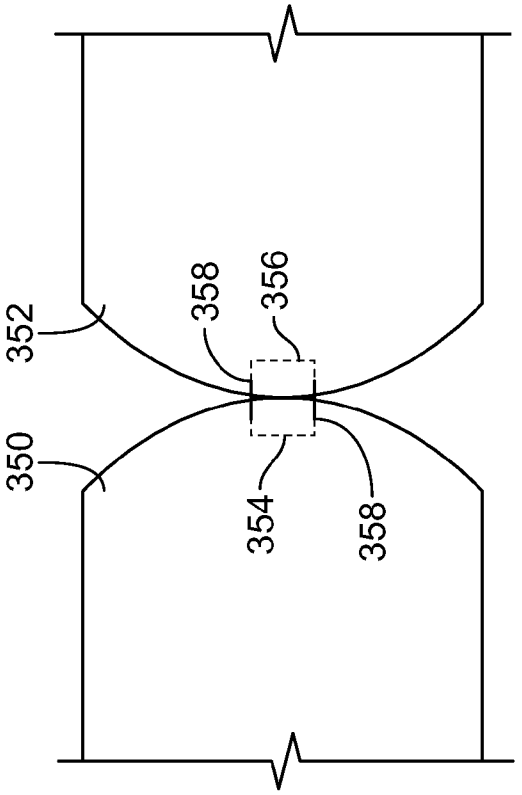

FIG. 41A

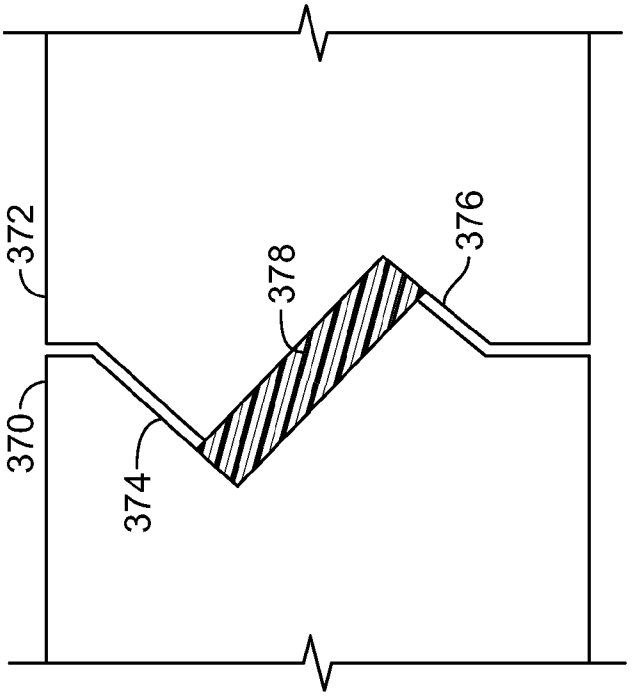

FIG. 43

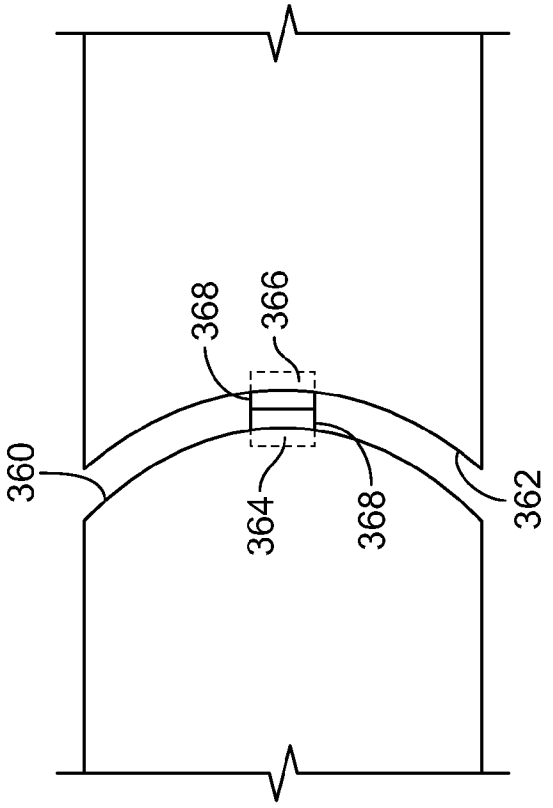

FIG. 42

CONNECTION SURFACE FOR A STRUCTURAL UNIT

PRIORITY CLAIM

[0001] This application is a continuation of U.S. patent application Ser. No. 14/081,976, filed Nov. 15, 2013, which is incorporated by reference herein. This application claims priority of U.S. Provisional Application Ser. No. 61/727,472, filed Nov. 16, 2012.

FIELD OF THE INVENTION

[0002] The subject disclosure relates to pavers, edgers, wall blocks, curbs, caps, precast wall panels, revetment mats, and other structural units, and in particular to connectors for structural units.

BACKGROUND OF THE INVENTION

[0003] It is well known to construct pavers, edgers, walls, curbs, caps, precast wall panels, revetment mats, and other structures with structural units. Such structural units can be manufactured from concrete, clay, brick, plastic, or various other materials.

SUMMARY OF THE INVENTION

[0004] An embodiment of the invention provides a connection surface that is disposed on at least a portion of a face of a structural unit. The connection surface comprises a first convex surface and a first concave surface arranged substantially along a first line. The shape of the first concave surface is complementary to the shape of the first convex surface. A second convex surface and a second concave surface are arranged substantially along a second line that is substantially parallel to the first line. The shape of the second concave surface is complementary to the shape of the second convex surface. The concave-convex order of the second line is reversed relative to the first line, such that the second convex surface corresponds with the first concave surface and the second concave surface corresponds with the first convex surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1** is a top plan view of two connected structural units according to a first embodiment of the invention.

[0006] FIG. **2***a* is a sectional view of the connected structural units of FIG. **1**, taken along line A-A and in the direction indicated.

[0007] FIG. **2***b* is a sectional view of the connected structural units of FIG. **1**, taken along line B-B and in the direction indicated.

[0008] FIG. **3***a* is an end view of one of the structural units of FIG. **1**.

[0009] FIG. **3***b* is an end view of another of the structural units of FIG. **1**.

[0010] FIGS. **4-5** are perspective views of a second embodiment structural unit.

[0011] FIG. **6** is a perspective view of a third embodiment structural unit.

[0012] FIG. **7** is a perspective view of two of the third embodiment structural units with connection surfaces facing one another.

[0013] FIG. **8** is a perspective view of a fourth embodiment structural unit having a beveled edge.

[0014] FIG. **9** is a perspective view of a fifth embodiment structural unit having irregular edges to provide a more natural stone appearance.

[0015] FIGS. **10-11** are perspective views of two fifth embodiment structural units with connection surfaces facing one another, with different ends of a second structural unit shown in FIGS. **10** and **11** respectively.

[0016] FIG. **12** is a perspective view of two of the fifth embodiment structural units connected end-to-end to form an angle.

[0017] FIG. **13** is a perspective view of two of the fifth embodiment structural units connected end-to-end to form a straight line.

[0018] FIG. **14** is a perspective view of one end of a wall section including two courses of the fifth embodiment structural units (the bottom rear structural unit is obscured) stacked in a half-bond arrangement.

[0019] FIG. **15** is a perspective view of an opposing end of the wall section of FIG. **14**.

[0020] FIG. **16** is a front end perspective view of the wall section of FIG. **14**.

[0021] FIG. **17** is a front perspective view of the wall section of FIG. **14**.

[0022] FIG. **18** is a top perspective view of two trapezoidal structural units according to a sixth embodiment with connection surfaces facing one another.

[0023] FIG. **19** is a perspective view of the two sixth embodiment structural units connected end-to-end to form a straight line, where one of the structural units is reversed in orientation.

[0024] FIG. **20** is a close-up perspective view of the connection surfaces of the two sixth embodiment structural units.

[0025] FIG. **21** is a perspective view of the two sixth embodiment structural units with connection surfaces facing one another, where both of the structural units have the same orientation.

[0026] FIG. **22** is a perspective view of the two sixth embodiment structural units of FIG. **21** connected end-to-end to form a curve.

[0027] FIGS. **23***a*-**23***b* are perspective views of a seventh embodiment structural unit having edges of convex portions that are partially beveled.

[0028] FIGS. **24***a*-**24***c* are perspective views of an eighth embodiment structural unit having edges of convex portions that are separated by a distance.

[0029] FIG. **25** is a perspective view of two ninth embodiment structural units having connection surfaces with three-dimensional shaped convex portions.

[0030] FIG. **26** is a perspective view of two tenth embodiment structural units having connection surfaces with arch-shaped convex portions.

[0031] FIG. **27** is an elevation view of a portion of an eleventh embodiment wall having cruciform shaped structural units.

[0032] FIG. **28** is an elevation view of a portion of a twelfth embodiment wall having hexagonal shaped structural units.

[0033] FIG. **29** is an elevation view of a portion of a thirteenth embodiment wall having glide shaped structural units.

[0034] FIG. **30** is a plan view of three fourteenth embodiment paving units connected and arranged in a 90/90/180 irregular rotation arrangement, and showing areas of connection using connection surfaces.

[0035] FIG. **31** is a perspective view of a fifteenth embodiment structure including irregular rock connection surfaces.

[0036] FIG. **32** is a perspective view of a wall connected to a pavement according to a sixteenth embodiment, in which wall blocks and paving units include connection surfaces that connect to one another.

[0037] FIG. **33** is a perspective view of a seventeenth embodiment structural unit having a connection surface disposed on a substantially central interior portion of an end face.

[0038] FIG. **34** is a perspective view of a portion of a wall according to an eighteenth embodiment including rotated panels connected to one another by connection surfaces disposed on side faces.

[0039] FIG. **35** is a perspective view of an end face of a block according to a nineteenth embodiment having a pair of connection surfaces that are center rotations of one another about a centerline.

[0040] FIG. **36** is a perspective view of a structural unit according to a twentieth embodiment having a pair of connection surfaces including a central connection surface disposed along a centerline of a side face and an outer connection surface that is split and disposed nearer to edges of the side face.

[0041] FIG. **37** is a perspective view of a structural unit according to a twenty-first embodiment having two sets of connection surfaces on a single end face to provide insets and offsets.

[0042] FIG. **38** is a perspective view of a portion of a connection surface according to a twenty-second embodiment, in which the convex and concave surfaces are arranged to allow offsetting in a wall either backward or forward with triple sets.

[0043] FIG. **39** is a plan view of a connection surface according to a twenty-third embodiment, in which the convex surfaces are domed and separated from concave surfaces by a space.

[0044] FIG. **40** is a plan view of a connection surface according to a twenty-fourth embodiment, in which the convex surfaces are truncated pyramids.

[0045] FIGS. **41**A and **41**B are elevation views of two connected convex surfaces of adjacent structural units according to a twenty-fifth embodiment including external connection surfaces disposed thereon.

[0046] FIG. **42** is an elevation view of a convex surface and a concave surface of adjacent structural units according to a twenty-sixth embodiment including external connection surfaces disposed thereon.

[0047] FIG. **43** is a section view of two adjacent structural units according to a twenty-seventh embodiment in which connection surfaces are configured to allow movement in one direction, but restrict movement in another.

DETAILED DESCRIPTION

[0048] Embodiments of the invention provide, among other things, a connection surface disposed on at least a portion of a face of a structural unit. Structural units, structures including structural units, and methods for connecting structural units are also provided herein. It will be understood that illustration and description of connection structures will be applicable to illustrate and describe connecting methods, and vice versa. "Structural unit" refers to any unit that can used to form part of a structure. A preferred structural unit is a concrete building unit, including but not limited to pavers, concrete masonry units, retaining wall blocks, patio stones, pavers, edgers, curbs, caps, precast wall panels, and revetment mats.

[0049] Turning now to the drawings, FIGS. **1-3** illustrate a first embodiment of the invention. First and second structural units, namely blocks **10**, **12** are shown having joined connection surfaces. Block **10** includes a connection surface having vertical halves **14**, **16** on a face of the block **10**, and block **12** includes a connection surface having vertical halves **18**, **20** on the face of the block **12**. As used herein, a connection surface "on" a face of a structural unit is intended to refer to a location on and/or in (partially or fully) the face of the structural unit.

[0050] FIG. **3***a* depicts the connection surface of the first block **10**. The connection surface includes a first convex surface **44** and a first concave surface **40**, extending substantially along a first horizontal line. The first concave surface **40** in this embodiment has an inward "V" shaped profile, and the first convex surface **44** has an outward "V" shaped profile that is complementary to the first concave surface. As used herein the term "complementary" means that the two surfaces have substantially the same configuration such that a convex surface of one unit can be at least partially received within a complementary concave surface of another unit.

[0051] The "complementary" surfaces need not be identical. Extending along a second horizontal line that is parallel to the first horizontal line are a second convex surface **42** and a second concave surface **46**. The second convex surface **42** has an outward "V" shaped profile, and the second concave surface has a complementary shaped inward "V" shaped profile. The first block **10** also has upper and lower flat surfaces **48**, **49**, such that the connection surface is disposed on an interior portion of the block face. In the first block **10**, the first concave surface **40** is also complementary to the shape of the second convex surface **42**, and the second concave surface **46** is also complementary to the first convex surface **44**, though this is not required in all embodiments.

[0052] As further shown in FIG. **3***a*, a concave-convex order of the second line is reversed relative to the first line. Particularly, along the first line, the first convex surface **44** is disposed on the left and the first concave surface **40** is disposed on the right, while along the second line, the second concave surface **46** is disposed on the left and the second convex surface **42** is disposed on the right. In this way, the second convex surface **42** corresponds with the first concave surface **40** and the second concave surface **46** corresponds with the first convex surface **42**.

[0053] Similarly, FIG. **3***b* shows the connection surface of the second block **12**. Specifically, the connection surface includes a first convex surface **50** and a first concave surface **54** extending along a first horizontal line, and a second concave surface **52** and a second convex surface **56** that extends along a second horizontal line parallel to the first line. The first and second convex surfaces **50**, **56** have an outward "V" profile, and the first and second concave surfaces **54**, **52** have a complementary inward "V" profile, so that the first convex surface is complementary to the first concave surface, and the second convex surface is complementary to the second concave surface. In block **12**, the first concave surface **54** is also complementary to the second convex surface **56**, and the second concave surface is also complementary to the first convex surface **50**.

[0054] Further, as with the first block **10**, a concave-convex order of the second line in block **12** is reversed relative to the first line. Thus, along the first line, the first convex surface **50**

is disposed on the left and the first concave surface **54** is disposed on the right, while along the second line, the second concave surface **52** is disposed on the left and the second convex surface **56** is disposed on the right.

[0055] The second convex surface **56** corresponds with the first concave surface **54**, and the second concave surface **52** corresponds with the first convex surface **50**. The second block **12** in this example embodiment also has upper and lower flat surfaces **58**, **59**.

[0056] Referring again to FIG. **3***a*, a first axis **70** extends (as shown, vertically) between the first convex surface and the first concave surface. The first concave surface **40** is substantially a reflection of the first convex surface **44** about the first axis **70**. Further, the first axis **70** extends between the second convex surface **42** and the second concave surface **46**. The second concave surface **46** is substantially a reflection of the second convex surface **42** about the first axis **70**. As used herein, "substantially" refers to meeting or approximating a condition sufficiently to provide a particular benefit, subject to manufacturing tolerances, natural or designed imperfections, deliberate aesthetic features, etc.

[0057] Additionally, in block **10**, a second axis **72** extends (as shown, horizontally) between the first convex surface **44** and the second concave surface **46**. The second concave surface **46** is substantially a reflection of the first convex surface **42** about the first axis **72**. The second axis **72** also extends between the second convex surface **42** and the first concave surface **46**. The first concave surface **46** is substantially a reflection of the second convex surface **42** about the second axis. Similar axes can be defined for block **12**.

[0058] FIG. **2***a* shows two engagements of the example connection surfaces for the blocks **10**, **12**. A first engagement **22** is formed where convex surface **50** of block **12** is received in concave surface **40** of block **10**. A second engagement **24** is formed where convex surface **42** of block **10** is received in concave surface **52** of the second block **12**. The complementary surfaces of the units engaging at **22**, **24** forms a general S-shape as can be seen in FIG. **2***a*, herein referred to as an "S-connection." This S-connection restrains vertical movement between the blocks **10**, **12**.

[0059] Similarly (but reversed in direction), FIG. **2***b* shows an engagement **32** wherein convex surface **44** of block **10** is received by concave surface **54** of block **12**. A second engagement **34** is formed where convex surface **56** of block **12** is received in concave surface **46** of block **10**. The complementary surfaces of the two units engaging at **32**, **34** also forms a general S-shape, albeit reversed, which also restrains vertical movement.

[0060] Together, the S-connections of the vertical halves **14**, **18** may be referred to as a "double S-connection." Further, because the S-connections of the vertical halves are reversed with respect to one another, lateral movement of the blocks **10**, **12** with respect to one another is constrained as well. Thus, the double S-connection restrains both vertical and horizontal movement between the blocks **10**, **12**.

[0061] In the embodiment of FIGS. **1-3** the "S" shape of the connection in the vertical plane is angular as shown in FIGS. **2***a* and **2***b*. However, in other embodiments, as will become more apparent below, the "S" shape maybe smoothly curved, box-shaped, regular or irregular. Herein, the term "S-shape" or "S-connection" is used in its broadest sense to mean any shape that is a center 180 degree rotation having one end that is generally convex and the other end being a substantially concave reflection thereof.

[0062] Further, in this embodiment, the mating block faces include upper flat surfaces **48**, **58** that engage at **26** in FIG. **2***a*, and the lower flat surfaces **49**, **59** engage at **28**. In the present embodiment the surfaces engaging at locations **22**, **24**, **26**, **28**, **32**, **34** may engage closely as shown, which would prevent the transmission of light, sand, soil or other materials from one side of the block to the other. However, in other embodiments, a gap may be provided between one or more of the surfaces between the blocks **10**, **12**. The gap(s) can remain open to provide permeability or can be filled with other materials, such as neoprene, plastic or other resilient materials during manufacture or installation. Also, one or more engagements can be weight-bearing.

[0063] Because the convex/concave surfaces are reflections of one another about the vertical and horizontal axes, the orientation of the mating surface will be the same even when the block is inverted. Thus, for example in the embodiment of FIGS. **1-3**, if block **12** is flipped over, it will still connect with block **10**. This is especially valuable for connecting non-rectangular blocks, e.g., trapezoidal and asymmetric shapes, as will be appreciated by persons skilled in the art.

[0064] Various embodiments of structural units may have one or more connection surfaces. Further, one or more connection surfaces may be disposed at any structural unit face (plane, curved, irregular, or other outer face of the structural unit), or in any portion or portions of a face, and in any orientation. For example, a structural unit may have ends, sides, top, bottom, or any other face with one or more connection surfaces. Such connection surfaces can occupy an entire face of a unit, or only a portion of the structural unit face. Further, double S-connection surfaces can be centered on a face, or can be off-center. All combinations of connection surfaces, connection surface features (e.g., connection surface features shown or described in any embodiment herein), connection surface locations on a structural unit face, and orientations are contemplated including but not limited by the several embodiments shown and described herein. Structural units can be connected end to end forward, turned, or flipped, or otherwise connected in any combination to form surface coverings, walls, edges and combinations thereof.

[0065] Connection surfaces can be provided on the face of the structural unit, such as but limited to by being formed, e.g., molded or otherwise formed, into one or more faces of the structural unit. For example, FIGS. **4-5** show second embodiment structural units **80** having a double S-connection surface formed therein.

[0066] Structural units can comprise, as non-limiting examples, pavers, concrete masonry units (CMU), retaining wall blocks, patio stones and edgers. Example structural units, including connection surfaces, may be manufactured in any manner of substantially any material such as, but not limited to, concrete (including wet cast and dry cast), clay, plastic, ceramic, glass or composite materials. Wet cast and dry cast concrete are preferred for building units, such as pavers, CMU, retaining wall blocks, patio stones and edgers, curbs, caps, precast wall panels, revetment mats, and other units.

[0067] FIG. **6** shows a structural unit **84** according to a third embodiment having a double S-connection surface. FIG. **7** shows the connection surface of structural unit **84** facing juxtaposed to a second, like structural unit **86**, illustrating how the surfaces can engage.

[0068] FIG. **8** shows a structural unit **88** according to a fourth embodiment. Unit **88** has a first S-connection having a

convex surface **90** and complementary concave surface **92** that are in the shape of a triangular prism. A second S-connection including convex surface **94** and complementary concave surface **96** has a similar shape to convex surface **90** and concave surface **92** but includes a beveled edge to define truncated pyramids. As demonstrated by this embodiment, the configurations of the two S-connections need not be the same. Further, the two S-connections need not have the same depth dimension. For example, the convex portion **94** of the truncated pyramid-shape S-connection could project outwardly a greater distance than the convex portion **90** of the triangular prism-shaped S-connection to provide a spacing effect, or the convex portion could have a shorter depth for creating space or allowing movement.

[0069] The first and second convex and concave surfaces can be any of various three-dimensional shapes, including solid geometric shapes or irregular shapes. The convex and concave surfaces can include at least one partial geometric solid. In some embodiments, for instance, structural units can be configured to have a more natural appearance, and thus include imperfections, textures, slight mismatches, etc. The first concave surface, the first convex surface, the second concave surface, and/or the second convex surface can have a textured or non-textured outer surface. Example surfaces can have irregular rock-like surfaces. The shapes can also vary for particular applications, as will be appreciated by those skilled in the art having reference to the present disclosure.

[0070] Rounded and/or irregular profiles provide a more natural, stone-like appearance. For example, FIG. **9** shows a structural unit **100** according to a fifth embodiment having a double S-connection surface that is generally rounded and irregular to provide a natural, rock-like appearance. The rounded double S-connection surface includes convex curved surface **104**, which transitions to a concave curved surface **106** along line S **1**. The surfaces **104**, **106** are disposed between first **102** and second **108** generally rock-like surfaces **108**. Similarly, a convex curved surface **116** transitions to a concave curved surface **114** along line S**2**, parallel to line S**1**. The second portion is disposed between rock-like surfaces **112**, **118**. There is also a continuous transition laterally between convex curved surface **104** and concave curved surface **114** along horizontal line S**3**, and laterally between concave curved surface **106** and convex curved surface **116** along horizontal line S**4**. In this way, the lateral profiles of block **100** are also S-shaped along directions S**3** and S**4**. Lines S**3** and S**4** are substantially perpendicular to lines S**1** and S**2**. The convex and concave surfaces along lines S**1**, S**2**, S**3**, S**4** each define rounded, irregularly shaped S-profiles. The numbering of lines S**1**-S**4** is merely for convenience and does not reflect priority or sequence. For example, lines S**3** and S**4** can be considered as first and second lines.

[0071] The S-profiles of lines S**1**, S**2** are preferably symmetrical but reversed with respect to one another, as is the case with lines S**3** and S**4**. However, it is not necessary that the profiles of S**1**, S**2** be the same as S**3**, S**4**. Indeed, as one can observe from FIG. **9**, S-connections S**1**, S**2** are shorter in length than S-connections S**3**, S**4**. Although it is not strictly necessary, it is preferred that the general configuration of the convex and concave surfaces along lines S**3** and S**4** are complementary with one another. Further, in the block **100** embodiment, the configurations of convex-concave surfaces **104**,**106** and convex-concave surfaces **116**, **114** are reflections of one another about a horizontal axis. Thereby, one unit **100** can be flipped top-to-bottom and still mate with another unit **100**.

[0072] Structural units can be of essentially any shape. Example shapes include rectangular, trapezoidal, cruciform, glides, hexagonal or other polygonal, other geometric shapes, and irregularly shaped units. Double S-connection surfaces can be advantageously employed to connect and interlock adjacent structural units in a wide variety of structures, including but not limited to interior and exterior walls, retaining walls, pre-cast wall panels, caps, columns and other vertical structures, as shown for example in U.S. Pat. Nos. 3,394,521, 4,107,894, 6,557,818, 6,615,561 and 7,011,474; pavements, patios, walkways and other surface coverings as shown for example in U.S. Pat. Nos. 4,128,357, 4,919,565 and 7,393,155; edgers and curbs, as shown for example in U.S. Pat. No. 7,637,688; revetment mats, coast fortifications, and other protective structures, as shown for example in U.S. Pat. Nos. 6,558,074 and 6,863,472. Double S-connection surfaces can be used to join different size or shape structural units in multi-unit systems, as shown for example in U.S. Patent Publication No. 2005/0166517. All of the foregoing cited patents and publications are hereby incorporated by reference. Double S-connectors have particularly advantageous application in tessellated surface coverings comprising glides, flip glides, rotations, and other types of tessellations—both regular and irregular. Further, double S-connection surfaces can be utilized to join different types of structures, such as walls-to-pavers, and pavers-to-curbs, as shown in FIG. **32**, for example.

[0073] FIGS. **10**-**13** show example structural units **120**, **122** according to the fifth embodiment that are generally trapezoidal in plan view and have opposing ends with irregular double S-connection surfaces. In FIG. **10**, first ends **124** of structural units **120**, **122** are juxtaposed. In FIG. **11**, first end **124** of structural unit **120** is juxtaposed with a second end **126** of structural unit **122**. FIG. **12** shows a course in which the structural units **120**, **122** are connected first end to first end to form an angle. Additional units **120**, **122** can be connected to form a segmented arc or circle. FIG. **13** shows a course in which the structural units **120**, **122** are connected first end to second end to form a straight line. This effect can be achieved by flipping one unit top-to-bottom or turning one unit 180 degrees. Also, in a preferred embodiment, units **120**, **122** include false joints that contribute to the natural rock-like appearance. Further, the connecting faces of the units **120**, **122** do not engage tightly leaving gaps of variable width but substantially the same size and appearance as the false joints so that the mating faces between units are not readily apparent.

[0074] Structural units may be respectively arranged in rows, courses, columns, orthogonally, setback, rotationally, serpentine, or other arrangements. In example wall embodiments, the structural units are arranged to provide at least a second course on top of a first course. One or more double S-connection surfaces can be provided on the top and bottom faces of the units to thereby restrain movement between units in the horizontal plane. The structural wall units may also include double S-connection surfaces on the ends or sides of the units to thereby restrain movement between units in a vertical plane. Structural wall units in the second course are preferably staggered from left to right with respect to the structural units in the first course. Examples of staggered arrangement include, but are not limited to, running bond,

half bond, quarter bond, three-quarter bond, etc. For example, FIGS. **14-17** show wall sections including three blocks **130**, **132**, **134** according to the fifth embodiment. The blocks **130**, **132**, **134** are arranged in lower and upper courses having a half-bond arrangement. Other, non-staggered arrangements are possible, including stack bond arrangements. Blocks can be in a vertical (near vertical) or setback arrangement as well. Optionally, connection surfaces can be provided on top or bottom faces to provide connection between courses, on faces, or both for front-to-back connection. Courses with such connection surfaces can be connected in a running bond, quarter bond, three-quarter bond or other arrangements.

[0075] FIGS. **18-22** show structural units **140**, **142** according to a sixth embodiment, in which the structural units are generally trapezoidal and have double S-connection surfaces on opposing end faces. FIGS. **18-19** show the structural units **140**, **142** respectively in reverse orientation so that they are connected (FIG. **19**) end-to-end in a straight line. FIGS. **20-22** show the structural units **140**, **142** having the same orientation so that they are connected (FIG. **22**) end-to-end to form an angle. Complex courses, such as serpentine courses, and structures having such courses, can be provided by varying the orientation of arranged structural units.

[0076] FIGS. **23***a*-**23***b* show a structural unit **150** according to a seventh embodiment in which edges **152**, **154** of convex surfaces **156**, **158** are partially beveled to aid installation by guiding adjacent structural units into final position.

[0077] More specifically, in the FIG. **23** embodiment, convex surface **156** comprises a triangular prism having a substantially vertical end **162** (best viewed in FIG. **23***b*) and a beveled surface **160**. Optionally, the beveled surface **160** can extend all the way to the bottom of the concave portion.

[0078] FIGS. **24***a*-**24***c* show a structural unit **170** according to an eighth embodiment. In this embodiment, a double S-connection is formed by off-setting faces **172**, **174** such that convex portion **176** is aligned with concave portion **182** and convex portion **178** is aligned with concave portion **184**. A gap **180** is provided between the faces **172**, **174** for adjustment. The gap can be filled with alternative materials, such as neoprene, plastic, etc., either during manufacture or during installation. Alternatively, the gap can be left open.

[0079] FIG. **25** shows double S-connection surfaces **202**, **204** disposed on the ends of structural units **206**, **208** according to a ninth embodiment. The connection surfaces **202**, **204** include convex and concave surfaces that are generally cubic or rectangular-prism shaped. As discussed above, the "S" connection shape need not be a smooth curve, but can be block format as in this embodiment. The connection surfaces are disposed over the entire face, though in other embodiments, the connection surfaces can be disposed over less than the entire face. The fit between units need not be perfect, and can be intentionally imperfect for aesthetic and/or functional purposes.

[0080] FIG. **26** shows complementary connection surfaces **210**, **212** disposed at end faces of structural units **214**, **216** according to a tenth embodiment. The connection surfaces **210**, **212** include convex and concave surface that are a partial/truncated cylindrical shape. Connection surfaces can be load-bearing due to engagement of complementary surfaces.

[0081] FIG. **27** is a plan view of a structure **220** according to an eleventh embodiment that comprises a plurality of cruciform structural units **222** assembled to form a panel or mat. The structural units **222** are connected to one another via double S-connection surfaces **224**, two exemplary pairs being shown in FIG. **27**. FIG. **28** is a plan view of structure **230** according to a twelfth embodiment including hexagonal structural units **232**, connected to one another via pairs of double S-connection surfaces **234** (two exemplary pairs are shown in FIG. **28**). Additional pairs of connector can be used as will be appreciated by those of ordinary skill in the art. Mat structures can be used in highway walls or embankments, waterway linings or banks, as shore protection, or other applications as known in the art. The double S-connections of the invention has particular application in waterways, as the double S-configuration provides both lateral and vertical restraint between units, which can prevent or reduce overtipping, wherein rapidly flowing water over the surface exerts an up-force on the downstream edges of the structural units.

[0082] A surface covering, mat or panel structure can include openings in various shapes, e.g., geometric or irregular. The openings can be formed within units or can be defined spaces or gaps between structural units. The openings can be left as an open space, filled with permeable materials such as sand, filled organic materials such as soil and plants, filled with cement, gout or other adhesives, filled with cushioning materials, or even filled with secondary units, which can in some embodiments have a different shape, material composition and/or surface treatment as compared to the primary structural units. Connection surfaces on the mating sides of the joined structural units provide an easy connection. Structural units combined in this way, with or without secondary elements or other materials in openings, can be arranged to define various patterns, providing aesthetic qualities. Individual structural units, or groups of combined structural units, alone or with secondary elements disposed within openings, could be assembled as mats or panels. Cabling can run between structural units, for instance as shown in U.S. Pat. No. 6,558,074.

[0083] FIG. **29** is a plan view of a glide structure **240** according to a thirteenth embodiment comprising a plurality of curved structural units **242** connected to one another via pairs of connection surfaces **244** (two exemplary pairs are shown).

[0084] FIG. **30** shows a portion of a surface covering **250** including at least two surface covering units **252** according to a fourteenth embodiment. The surface covering units **252** are irregular rotational tessellation elements made in accordance with U.S. Pat. No. 7,393,155. One or more pairs of double S-connection surfaces **254** are provided to connect the units **252**. These connection surfaces **254** can be split along a face of the surface covering units **252**.

[0085] The double S-connection surface of the invention has particular application to surface coverings units such as pavers and patio stones. The double S-connection surfaces **250** provide a double lock, restraining adjacent units from moving vertically with respect to one another in addition horizontal restraint that typically provided in conventional horizontal interlocking systems. This can prevent an individual unit in a surface covering from tipping, sinking or being thrust upward due to an inconsistent foundation, erosion, frost heave, or other causes. Further, a pavement can be made permeable, e.g., water-permeable, if desired, or substantially impermeable to light, sand, soil, etc.

[0086] FIG. **31** shows a structural unit **260** according to a fifteenth embodiment. Unit **260** has connection surfaces **262***a*, **262***b*, **262***c*, **262***d*, **262***e*, **262***f* disposed on all sides (three are visible in FIG. **31**). It is also contemplated that the connection surfaces could be on fewer than all sides, and on

an interior portion of a particular side or sides. While the structural unit **260** profile generally defines a cube **264**, the connection surfaces **262***a-f* in unit **260** are configured to provide a "natural" irregular double S-connection. Among other advantages, such a configuration allows multiple units **260** to stacked on a skid with adjacent units interlocking with each other in both vertical and horizontal directions. Thereby, the units "hug" one another reducing abrasion between units, breakage and other damage in transportation. It is not required for all surfaces of the building blocks **260** (or other structural units disclosed herein) to touch, and gaps can be provided between units. Preferably, the connection surfaces **262***a*, **262***b*, **262***c*, **262***d*, **262***e*, **262***f* are configured to be substantially the same so that all faces of the unit **260** can mate with all faces of similarly configured units.

[0087] Structural units connected by double S-connection surfaces may be of the same type, or of different types. FIG. **32** shows an example structure **270** according to a sixteenth embodiment, including a wall structural unit **272** that is connected to a paver structural unit **274**, which is in turn connected to a curb structural unit **276**. Mating double S-connection surfaces **278** disposed on opposing faces of the units **272**, **274**, **276** connect the units, and thus different types of structures, to one another. Any combinations of two or more structural unit types are contemplated herein. Non-limiting examples include wall systems to paver systems, retaining wall systems to paver systems, edger systems to patios, walls to pavers and edgers, walls to caps, pavers to curbings, precast wall panels to pavers, walls to revetment mats, etc. Those of ordinary skill in the art will appreciate suitable positions for connection surfaces for mating structural units of different types.

[0088] The position of the connection surface on a face of a structural unit can be over the entire face, or a portion of a face. Further, where the connection surface is disposed on a portion of a face, the connection surface can be disposed at any location on the structural unit face. As one example, FIG. **33** shows a structural unit **280** according to a seventeenth embodiment having a connection surface **282** disposed on an end face **284**, and located at a central interior portion. The connection surface **282** can be disposed away from the center of the face in other embodiments.

[0089] FIG. **34** shows a wall structure comprised of a plurality of structural panel units **290** according to an eighteenth embodiment. The panel units **290** include double S-connection surfaces **292** disposed at each of four end faces **294**. Preferably the double S-connection surface is centered on each end face. Accordingly, each panel unit can be assembled in the same direction, alternative directions, i.e., parquet as shown, or quarter turn.

[0090] Structural units can have more than one double S-connection on a single face. FIG. **35** shows a structural unit **300** according to a nineteenth embodiment having a pair of double S-connection surfaces **302**, **304** disposed on an end face **306** of the structural unit **300**. The connection surfaces **302**, **304** can be configured as images rotated about center line **308**. It is also contemplated to split the connection surface in half vertically, so that, for instance, a single S is on top and a single S is on bottom. The connection surface can also be split in half horizontally. Third, fourth, or additional double S-connection surfaces can also be provided on a single building unit surface or on a combination of faces. When multiple double S-connection surfaces are employed, each connector need not be the same size or shape as the other S-connection surfaces. A full double S can be disposed on top and bottom portions of the face **306**, or a double S can be split and disposed such that half is on top and half is on bottom, provided that the halves are substantially equidistant from the center line **308**.

[0091] FIG. **36** shows a structural unit **310** according to a twentieth embodiment having a double S-connection surface disposed on a face **306**. The double S-connection surface is split into first and second portions **316***a*, **316***b*, each of which are substantially equidistant from a center line **308**. This arrangement helps resist tipping or twisting of connected units. In the FIG. **36** embodiment, centers of the first and second portions **316***a*, **316***b* are separated from respective left and right edges at a quarter of the distance across the length of the face **306**, so that the center of first portion **316***a* is separated from each of the left edge and from the center line **308** by a distance A, and the center of second portion **316***b* is separated from each of the center line **308** and the right edge by the same distance A. Split portions alternatively can be disposed horizontally or vertically adjacent to one another. Optionally and preferably, the double S-connection surfaces are spaced along the side face of the unit so that the units can be assembled in ¼, ½, ¾ or stacked bond relationship.

[0092] FIG. **37** shows a structural unit **320** according to a twenty-first embodiment having two sets of double S-connection surfaces **322** on each end face **324**. Any number of pairs or sets can be provided. As provided above, one or more single units can also be split down a center as well. This arrangement may be used to generate recessed panels (I), projecting panels (P) or slanting panels (S) in a wall or panel structure as shown in FIG. **38**. Specifically, by selectively mating inner connecting surfaces with outer connecting adjacent panels can be recessed, projected or slanted relative to each other. As one example, curves can be provided by progressively stepping panels in/out relative to each other. Spaces may be provided between concave surfaces and complementary convex surfaces, in vertical and/or horizontal directions. FIG. **39** shows a structural unit face **336** according to a twenty-third embodiment, in which partial cylindrical convex surface **338** and complementary concave surface **340** surfaces are separated from one another by spaces **342**. FIG. **40** shows another unit face **350** according to a twenty-fourth embodiment similar to connection surface **336**, but with truncated pyramid shaped convex **338** and complementary concave **340** surfaces.

[0093] While some example embodiments include double S-connection surfaces that are integrated, e.g., formed, into a face of a structural unit, other embodiment double S-connection surfaces can be alternatively or additionally provided by external elements that are disposed on the face and are attached, adhered or otherwise coupled to the face. External elements may include, as non-limiting examples, convex and concave surfaces formed in any suitable manner, such as by molding into an external face. The concave and convex surfaces of such connection surfaces can be configured similarly to any of the other concave and convex surfaces shown or described elsewhere herein.

[0094] External elements may also be used as a key, and connected to a receiving hole. For example, FIG. **41** shows two convex faces **350**, **352** according to a twenty-fifth embodiment. The convex faces **350**, **352** include insets **354**, **356**, in which are disposed external double S-connection surfaces **358**. For example, the external connection surfaces **358** may be plugged into the insets **354**, **356**, which provide a receiving core for the connection surfaces. The connection

surfaces **358** are configured according to any of the connection surface embodiments disclosed herein. Alternatively, the connection surface **358** can be integrated into the faces **350**, **352**. FIG. **42** shows a convex face **360** and a concave face **362** according to a twenty-sixth embodiment, which include opposing insets **364**, **366**, each of which has an external double S-connection surface **368** disposed therein. The connection surface **368** can be configured similarly to the external connection surface **358**.

[0095] Example connection surfaces can be configured to allow some movement in one direction providing a tighter restraint in another direction. For example, FIG. **43** shows two structural units **370**, **372** having connection surfaces **374**, **376** configured such that a space **378** is defined between the units either along a vertical direction (as shown in FIG. **43**) or in a horizontal direction. One S is visible in FIG. **43**. The other S (not shown) preferably has substantially the same spacing. Such a space can be provided by controlling manufacturing tolerances, for instance, making the concave surfaces deeper than the convex surfaces. Alternatively, the concave surfaces can be made longer than the convex surfaces. In the embodiment shown in FIG. **43**, the space **378** allows the structural units **370**, **372** to move in a vertical direction with respect to one another, while still constraining movement along the horizontal direction. The space **378** can be fully or partially filled with material, e.g., a pad (not shown) e.g., for cushioning, or may be a clear space. To allow movement in the later direction, a space may be provided such as space **180** (see FIG. **24***b*). A pad or other material may be provided in the space **180**.

[0096] Example connection surfaces, structural units, and structures can include any combination of features shown and/or described herein. The particular connection surface shown and described herein are merely examples, and those of ordinary skill in the art will appreciate that many other configurations for connection surfaces are possible, and such additional configurations are intended to fall under the scope of the present invention.

[0097] Structures can be or include vertical, horizontal, flat, curved, complex or irregular, largely two-dimensional, and/or largely three-dimensional structures. Structures can include a plurality of structural units, including any of the structural units shown or described herein, including any combinations of structural units, and including any of the connection surfaces, including combinations of connection surfaces, shown or described herein. The structure may be a complete, stand-alone structure, or may be combined with other structural units to provide a larger structure. Example structures include, but are not limited to, walls (e.g., retaining walls, interior walls, exterior walls, sound walls, etc.), wall veneers, wall panels, column blocks highway panels, other panels, pavements, edges or combinations thereof.

[0098] While various embodiments of the present invention have been shown and described, it should be understood that other modifications, substitutions, and alternatives are apparent to one of ordinary skill in the art. Such modifications, substitutions, and alternatives can be made without departing from the spirit and scope of the invention, which should be determined from the appended claims.

[0099] Various features of the invention are set forth in the appended claims.

What is claimed is:

1. A connection surface disposed on a face of a structural unit, the connection surface comprising:

a first convex surface and a first concave surface, the first convex surface and first concave surface being arranged substantially along a first line, the shape of the first concave surface being complementary to the shape of the first convex surface; and

a second convex surface and a second concave surface, the second convex surface and second concave surface being arranged substantially along a second line that is substantially parallel to the first line, the shape of the second concave surface being complementary to the shape of the second convex surface;

wherein a concave-convex order of the second line is reversed relative to the first line such that the second convex surface corresponds to the first concave surface and the second concave surface corresponds to the first convex surface.

2. The connection surface of claim **1** wherein the first and second convex surfaces and first and second concave surfaces each comprise at least one partial geometric solid.

3. The connection surface of claim **1** wherein the first convex and second concave surfaces together define a third S profile, and wherein the second concave and first convex surfaces together define a fourth S profile that is symmetrical but reversed with respect to the third S profile.

4. The connection surface of claim **3** wherein the profile of the first and second S profiles is different from the profile of the third and fourth S profiles.

5. The connection surface of claim **1** wherein the first convex surface and first concave surface are separated by a first distance, and wherein the second concave and second convex surfaces are separated by a second distance.

6. The connection surface of claim **5** wherein the second distance is substantially equal to the first distance.

7. The connection surface of claim **6** wherein the first and second lines are separated by a third distance that is substantially equal to the first distance.

8. A structural unit comprising:

a plurality of faces;

at least one connection surface disposed on each of at least two of the plurality of faces;

wherein each connection surface comprises:

a first convex surface and a first concave surface, the first convex surface and first concave surface being arranged substantially along a first line, the shape of the first concave surface being complementary to the shape of the first convex surface; and

a second convex surface and a second concave surface, the second convex surface and second concave surface being arranged substantially along a second line that is substantially parallel to the first line, the shape of the second concave surface being complementary to the shape of the second convex surface;

wherein a concave-convex order of the second line is reversed relative to the first line such that the second convex surface corresponds to the first concave surface and the second concave surface corresponds to the first convex surface.

9. The structural unit of claim **8** wherein the structural unit comprises a molded concrete building unit.

10. The structural unit of claim **8** wherein the unit has a first and opposite second face, each said face having a connection surface thereon.

11. The structural unit of claim **10** where the first and second faces are substantially parallel.

12. The structural unit of claim **10** wherein the unit first and second faces are not substantially parallel.

13. A structure comprising:

a plurality of structural units including at least first and second structural units, each of the plurality of structural units comprising a plurality of faces including at least a first and second face, each of said first and second faces having at least one connection surface;

wherein each connection surface comprises:

a first convex surface and a first concave surface, the first convex surface and first concave surface being arranged substantially along a first line, the shape of the first concave surface being complementary to the shape of the first convex surface; and

a second convex surface and a second concave surface, the second convex surface and second concave surface being arranged substantially along a second line that is substantially parallel to the first line, the shape of the second concave surface being complementary to the shape of the second convex surface;

wherein a concave-convex order of the second line is reversed relative to the first line such that the second convex surface corresponds to the first concave surface and the second concave surface corresponds to the first convex surface;

wherein connection surfaces of the first and second structural units are coupled to one another such that the first and second concave surfaces of the connection surface of the first structural unit at least partially receive the first and second convex surfaces of the connection surface of the second structural unit, and such that the first and second concave surfaces of the connection surface of the second structural unit at least partially receive the first and second convex surfaces of the connection surface of the first structural unit.

14. The structure of claim **13** wherein the connection surfaces are coupled to one another such that the first and second structural units are constrained from either horizontal or vertical movement with respect to one another, but are less constrained for the other of horizontal or vertical with respect to one another.

15. The structure of claim **13** wherein a gap is defined between mating faces of the first and second structural units that is permeable to liquid.

16. The structure of claim **13** wherein the connection interface between the first and second structural units is substantially impermeable to light, sand and soil.

17. The structure of claim **13** wherein the first and second structural units are of different sizes and/or different shapes.

18. The structure of claim **13** wherein the structure comprises at least a third structural unit;

wherein the third structural unit comprises at least two connection surfaces on a single face;

wherein connection surfaces of the first and second structural units are coupled to respective ones of the at least two connection surfaces on the third structural unit.

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