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(54) **FLEXIBLE MAT FORMING SYSTEM AND METHOD**

(57) In an exemplary embodiment, a system (300) for forming a flexible mat (74) having an open mesh (358) embedded in and interconnecting a plurality of blocks (76) of a hardened paste includes a rotating drum (314) having a plurality of mold cavities (324) about an outer periphery thereof that receive a hardenable paste (25); a sheet of the open mesh that is fed over the mold cavities so that the mesh is embedded in the hardenable paste

deposited in the mold cavities; and a flexible sheet (302) that is placed against the outer periphery of the drum over the mold cavities containing the hardenable paste and the sheet of open mesh of the rotating drum to retain the hardenable paste within the mold cavities and retain the open mesh embedded in the hardenable paste as the hardenable paste solidifies to form the flexible mat.

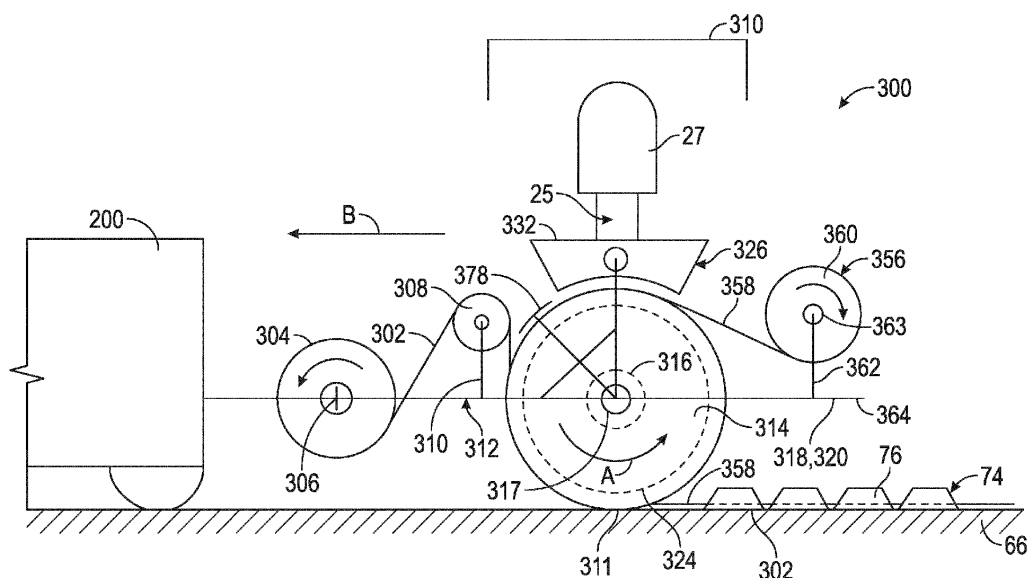


FIG. 9

Description

TECHNICAL FIELD

[0001] The present disclosure relates to systems and methods for forming flexible tied block mats, and more particularly, to systems and methods for forming continuous flexible tied block erosion control mats.

BACKGROUND

[0002] Erosion is a natural process in which meteorological elements such as rain, wind, and snow remove soil, rock, and dissolved material from one location on the Earth's crust and transport it to another location. While such erosion is a natural process, certain localized human activity increases the rate of erosion to many times that at which erosion occurs naturally. Land surfaces adjacent man-made structures such as canals, roads, reservoirs and ponds, and artificially created drainage channels and other waterways are particularly susceptible to erosion because naturally occurring indigenous vegetation is removed in order to form the structures.

[0003] Erosion can be mitigated in these areas by remediation of the land surface adjacent the canal, road, or channel by planting vegetation to replace the vegetation that was stripped away during construction. However, there is a time interval between the planting of the replacement vegetation and the point at which the replacement vegetation is sufficiently developed to prevent further erosion of surface soil during which further erosion may occur.

[0004] Efforts have been made to retain the surface soil in place in these areas until such time as vegetation can mature to the point where the root structure of the vegetation retains the soil in place. An example of such material is the flexible mat structure disclosed in United States Patent No. 6,793,858 titled "Method and Apparatus for Forming a Flexible Mat Defined by Interconnected Concrete Panels," the entire contents of which are incorporated herein by reference. That patent discloses a flexible mat structure in the form of spaced, interconnected concrete panels or blocks held together by an open mesh of a polymeric material.

[0005] The flexible mat structure may be made by depositing concrete in the block-shaped mold cavities formed in the surface of a rotating drum and embedding in the concrete material the open mesh structure. While the method is effective, there is a need to introduce additional efficiencies in the manufacture of such flexible mat structure.

SUMMARY

[0006] The present disclosure describes a flexible mat forming system and method in which improvements have been made to increase the quality of the flexible mat prod-

uct produced and the efficiency in the process of manufacturing the flexible mat. One type of mat produced by the process and system is known as a tied block mat, in which blocks of cement are cast in a pattern onto a sheet of geogrid. Such a tied block mat is ideal for applying to the ground adjacent airport runways, taxiways and terminals, roadbeds, and the banks of reservoirs, canals, rivers and other waterways, shorelines, and any sloped surface to control erosion. In some embodiments, the system and process produces a tied block mat that is sufficiently sturdy to function as a drivable surface.

[0007] In one embodiment, a system for forming a flexible mat having an open mesh embedded in and interconnecting a plurality of blocks of a hardened paste includes a rotating drum having a plurality of mold cavities about an outer periphery thereof that receive a hardenable paste; a sheet of the open mesh that is fed over the mold cavities so that the mesh is embedded in the hardenable paste deposited in the mold cavities; and a flexible sheet that is placed against the outer periphery of the drum over the mold cavities containing the hardenable paste and the sheet of open mesh of the rotating drum to retain the hardenable paste within the mold cavities and retain the open mesh embedded in the hardenable paste as the hardenable paste solidifies to form the flexible mat.

[0008] In another embodiment, a system for forming a flexible mat having an open mesh embedded in and interconnecting a plurality of blocks of a hardened paste includes a frame; a cylindrical drum rotatably mounted on the frame and contacting the ground, the drum having a plurality of mold cavities about an outer periphery thereof that receive a hardenable paste; a sheet of the open mesh that is carried on a support mounted on the frame, the open mesh fed over the mold cavities so that the mesh is embedded in the hardenable paste deposited in the mold cavities; and a flexible sheet that is carried on a roll mounted on the frame, the sheet placed against the outer periphery of the drum over the mold cavities containing the hardenable paste and the sheet of open mesh and extending downwardly to a pinch point between the drum the ground to retain the hardenable paste within the mold cavities and retain the open mesh embedded in the hardenable paste as the hardenable paste solidifies to form the flexible mat.

[0009] In yet another embodiment, a method for forming a flexible mat having an open mesh embedded in and interconnecting a plurality of blocks of a hardened paste includes rotating a drum having a plurality of mold cavities about an outer periphery thereof; depositing a hardenable paste in the mold cavities; feeding a sheet of the open mesh over the mold cavities so that the mesh is embedded in the hardenable paste deposited in the mold cavities; and placing a flexible sheet that is placed against the outer periphery of the drum over the mold cavities containing the hardenable paste and the sheet of open mesh to retain the hardenable paste within the mold cavities and retain the open mesh embedded in the harden-

able paste as the hardenable paste solidifies to form the flexible mat.

[0010] Other objects and advantages of the disclosed flexible mat forming system will be apparent from the following description, the accompanying drawings, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

Fig. 1 is a schematic, side elevational view of an embodiment of the disclosed flexible mat forming system;

Fig. 2 is a schematic, front elevational view of the flexible mat forming system of Fig. 1;

Fig. 3 is a detail perspective view of the flexible mat forming system of Fig. 1, showing the retaining plate;

Fig. 4 is a perspective view of the flexible mat forming system of Fig. 1, taken from the rear of the hopper and drum;

Fig. 5 is a detail showing an embodiment of a rotating auger located within the hopper of the flexible mat forming system of Fig. 1;

Fig. 6 is a detail perspective view of a section of the hopper of Fig. 5;

Fig. 7 is a detail perspective view showing a portion of the bottom plate of the hopper of the flexible mat forming system of Fig. 1;

Fig. 8 is an end elevation of the flexible mat of Fig. 1, formed into a roll;

Fig. 9 is a schematic side elevation of another embodiment of the invention; and

Fig. 10 is a schematic side elevation of a movable frame or bridge for separating the flexible mat from the flexible sheet.

DETAILED DESCRIPTION

[0012] The disclosed flexible mat forming system, generally designated 10, is shown in Figs. 1, 2, and 4. The system 10 may include a frame 12 on which is mounted an elongate, rotatable cylindrical drum 14. The drum 14 may be rotated by a motor 16, which in embodiments may be an electric motor or a hydraulic motor, in which case the system 10 is self-propelled, or assists in propelling itself. The motor 16 may rotate the drum in a counterclockwise direction, as indicated by arrow **A** in Figs. 1 and 4. In other embodiments, system 10 does not have

a motor 16, but instead the drum 14 rests on the ground 66 and rotates in the direction of arrow **A** as a result of friction with the ground from the frame 12 being pulled over the ground, which in Fig. 1 would be to the left. In an embodiment, the frame 12 may include a pair of horizontal beams 18, 20 on which the drum 14 is rotatably mounted, for example by a journal bearing 17.

[0013] As shown in Fig. 4, in an exemplary embodiment, the drum 14 includes a plurality of transverse rows 22 of mold cavities 24 that are formed about the outer periphery, or cylindrical outer surface, of the drum. In other embodiments, the mold cavities 24 are arranged in a pattern or patterns on the drum. In embodiments, the patterns are selected from a rectilinear, transverse row of the mold cavities, a staggered pattern of the mold cavities, a checked pattern of the mold cavities, a random pattern of the mold cavities, a running bond pattern of the mold cavities, and combinations of the foregoing. With such embodiments, the term transverse row 22, as used herein, includes any spacing or arrangement or pattern of the mold cavities 24 along the length of the outer periphery of the drum 14, including the aforementioned patterns, and is not limited to a rectilinear row parallel to a central rotational axis of the drum 14.

[0014] Accordingly, the drum 14, which in embodiments takes the form of an elongated cylinder, is a form having mold cavities 24. In embodiments, the mold cavities 24 may be shaped to receive hardenable paste 25 from a chute 27 (see Figs. 1 and 2) from the drum of a concrete transport truck, or from a concrete pump, or from a concrete mixer trailer, and form the hardenable paste 25 blocks 76, which in embodiments may be square at their base. For example, the mold cavities 24 may be shaped to form pyramidal blocks 76 of hardenable paste 25 received from the hopper 26 having square bases $6\frac{1}{2}" \times 6\frac{1}{2}"$ and $2\frac{1}{4}"$ high, although the mold cavities may have other shapes and dimensions. For example, the mold cavities 24 may be shaped to form blocks 76 having shapes selected from rectangular, square, hexagonal, octagonal, round, elliptical, irregular, and combinations of the foregoing.

[0015] As shown in Figs. 1, 2, and 4, the system 10 also may include an elongate hopper, generally designated 26, adjacent the drum 14. In an embodiment, the hopper 26 is positioned directly above the drum at the 12 o'clock position, such that the hopper is positioned above an uppermost one of the plurality of transverse rows 22 of mold cavities 24. In other embodiments, the hopper 26 is positioned relative to the drum 14 upstream of the 12 o'clock position, for example at the 2 o'clock position, and in still other embodiments, the hopper is positioned relative to the drum 14 downstream of the 12 o'clock position, for example at the 10 o'clock position. In other embodiments, the hopper 26 is positioned adjacent the drum 14 in locations between the 3 o'clock position and the 9 o'clock position.

[0016] In an embodiment, the hopper 26 is shaped to receive a hardenable paste 25 and deposit the harden-

able paste into mold cavities 24 facing the hopper. In an embodiment in which the mold cavities 24 are arranged in rectilinear transverse rows 22, the hopper 26 deposits the hardenable paste 25 along a facing row 28 (see Fig. 7) of the plurality of transverse rows 22 of mold cavities 24. The hopper 26 may include an open upper portion 30 having an open top 32 and downwardly extending and converging front and rear walls 34, 36, respectively. The hopper 26 may include a central section 38 having front and rear walls 40, 42, respectively, shaped to form a trough with an arcuate bottom, and a lower section 44 having downwardly and outwardly diverging forward and rearward lower walls 46, 48, respectively.

[0017] Front and rear walls 34, 36 of the hopper 26 define frontward and rearward facing surfaces, respectively. Side walls 40, 42 define forward and rearward facing walls, respectively, and forward and rearward lower walls 48, 46 define forward and rearward facing walls, respectively. The front and rear walls 34, 36, side walls 40, 42, and forward and rearward lower walls 46, 48 are closed at opposing sides by lateral walls 50, 52 to define an interior chamber 54, as shown in Figs. 5 and 6. In embodiments, the hopper 26 includes a bottom panel 122 that in some embodiments is shaped to conform to the curvature of the outer periphery of the drum 14. As will be described, in embodiments the arcuate shape of the bottom panel 122 may support the remainder of the hopper 26 on top of the drum 14, and in other embodiments, permit a close spacing between the hopper and the top of the drum.

[0018] In embodiments, the system 10 includes a support, generally designated 56, which takes the form of a spool assembly having a spindle or rotating axle, for supporting a sheet 58 of open mesh, from a roll 60 on the spool assembly 56, between the hopper 26 and the facing row 28 (see Fig. 7) of the plurality of transverse rows 22 of mold cavities 24. In embodiments, the spool assembly 56 includes a pair of posts 62 to which a spindle or axle 63 is attached and extends therebetween. The support 56 may be mounted on a rear platform 64 of the frame 12. In an exemplary embodiment, the rear platform 64 is supported above the ground 66 by a pair of rear wheels 68 and a pair of front wheels 70. In embodiments, the spindle 63 is mounted on the posts 62 for free rotation relative to the support; in other embodiments the spindle is motorized to assist in paying out the sheet 58 of open mesh.

[0019] In an embodiment, the sheet 58 of open mesh, is a sheet of geogrid, and in other embodiments is a sheet of open mesh made of a polymer, which may be a bi-axial geogrid material such as polyester or polypropylene. An example of such a polypropylene mesh is Fornit 30/30 geogrid manufactured by Huesker Inc. of Charlotte, North Carolina. In an embodiment, the sheet 58 of open mesh is fed forwardly, that is, to the left in Fig. 1, under guide tube 72, which is mounted on the frame 12 and extends transversely adjacent the drum 14, and either over or under a transverse guide member 73, where

it continues, passing beneath the hopper 26 and above the drum 14.

[0020] A hardenable paste 25 deposited into the open top 32 of the hopper 26, and in an exemplary embodiment falls downwardly through the hopper and into the facing row 28 of the plurality of transverse rows 22 where it is retained within the mold cavities 24. In embodiments, the hardenable paste 25 is a fresh cement paste such as Portland cement, and in a particular embodiment, is 5000 psi., wet-cast Portland cement. In other embodiments, the hardenable paste 25 is selected from concrete, a mixture of Portland cement, sand, and/or gravel, and a polymer. The sheet 58 of open mesh becomes embedded in the hardenable paste 25 and the combination of mesh and paste continues as the drum 14 rotates in the direction of arrow **A** in a downstream direction away from the hopper 26 where the paste hardens and the combination of mesh and paste leaves the lower portion of the drum 14 as a flexible mat, generally designated 74, of blocks 76 of hardened paste material held together by the sheet 58 of geogrid mesh, also known as a tied concrete (i.e., hydraulic Portland cement) block mat when concrete is used as the hardenable paste 25. A sheet of such a tied block mat is suitable for applying to the ground for purposes of erosion control.

[0021] As shown in Figs. 1, 2, 3, and 4, in an embodiment, a retaining plate, generally designated 78, extends partially about the outer periphery of the drum 14 and is positioned on the downstream side 80 of the drum and hopper 26. The retaining plate 78 may be spaced sufficiently close to the outer periphery of the drum to retain the sheet 58 of open mesh against the outer periphery of the drum and the hardenable paste 25 within the mold cavities 24 passing between the retaining plate and the outer periphery of the drum 14.

[0022] In an embodiment, the retaining plate 78 may be shaped to conform to the curvature of the outer periphery of the drum 14. Also in an embodiment, the retaining plate may be imperforate, comprising a single sheet of curved sheet metal. In other embodiments, the retaining plate 78 is made of an aluminum alloy, or a woven or nonwoven mat of a geosynthetic, such as polypropylene, a nylon, other polymers, a polyamide material, or combinations of the foregoing. In the embodiment shown in Figs. 1-4, the frame 12 supports the drum 14 and hopper 26, and the hopper is positioned above an uppermost one of the plurality of transverse rows 22 of mold cavities 24. Further, the retaining plate 78 may be attached to the frame 12.

[0023] The retaining plate 78 may include an upper retaining member, generally designated 82, that may be attached to the frame 12 for holding an upper portion of the retaining plate 78 against the outer periphery of the drum 14. The upper retaining member 82 may include an adjustable connection, which may take the form of adjustable cables or chains 86, 88 having ratchets incorporated therein for manually lengthening and shortening their lengths. The adjustable cables or chains 86, 88 may

extend from their upper ends, which may be attached to upright supports 90, 92 of the frame 12 and are attached at their lower ends to the upper retaining member 82.

[0024] By adjusting the lengths of the cables or chains 86, 88, the spacing between the retaining plate 78 and the hopper 26 may be adjusted. Further, the spacing between the outer periphery of the drum 14 and the retaining plate 78 may be varied by adjusting the lengths of the cables or chains 86, 88. In an embodiment, the upper retaining member 82 may take the form of an upper retaining bar extending transversely of the retaining plate 78. Another function of the adjustable cables or chains 86, 88 is that they may be lengthened or shortened to adjust the height of the retaining plate 78 above the ground 66. This enables the point at which the flexible mat 74 is no longer held against the outer periphery of the drum 14 and may begin to separate from the drum.

[0025] As shown in Figs. 1-4, the system 10 may include a lower retaining member 94 that holds a lower portion of the retaining plate 78 against the outer periphery of the drum 14. The lower retaining member 94 may urge a lower edge of the retaining plate 78 against the drum 14 outer periphery. In an embodiment, the lower retaining member 94 may take the form of a lower retaining bar or a round pipe that extends transversely of the retaining plate 78. The lower retaining member 94 may include left and right adjustment arms 96, 98. The adjustment arms 96, 98 may be attached to the frame 12 and be adjustable in length to vary a force exerted by the lower retaining member 94 against the retaining plate 78, and thus the force exerted by the retaining plate against a lower portion of the outer periphery of the drum 14. The adjustment arms 96, 98 may take the form a pair of adjustable straps, each attached to the frame 12.

[0026] In embodiments, the lower retaining member 94 may not be attached to the retaining plate 78, but only urged against it, thereby allowing relative slidable movement between the lower retaining member and the shield, for example, in response to height adjustment by cables or chains 86, 88. In such an embodiment, support chains 97, 99, each extending between and interconnecting the lower retaining member 94 and the upright supports 90, 92 of the frame 12, may support the lower retaining member 94 at a pre-set, desired height above the ground 66 and relative to the retaining plate 78.

[0027] As shown in Figs. 1 and 2, the retaining plate 78 may operate to hold the sheet 58 of open mesh, which in an embodiment may be a geogrid or other geosynthetic material, against the outer periphery of the drum 14 as the open mesh and rows 22 of mold cavities 24 pass beneath the hopper 26 in a downstream direction, indicated by arrow A, away from the hopper and extend downwardly toward the ground 66. As the rows of mold cavities 24 pass downstream of the hopper 26, they receive a hardenable paste 25, which in an embodiment may be fresh (i.e., flowable and not yet hardened) cement paste, and the sheet 58 of geogrid open mesh may become embedded in the fresh cement paste, and the ce-

ment paste hardens as the drum 14 rotates the combination mesh and cement paste between the retaining plate 78 and drum 14. At the lowermost portion of the drum 14, the paste 25 has hardened, in embodiments at least enough to be dimensionally stable, forming the mesh and block combination 75, also known as a tied concrete block mat, shown in Fig. 1. In embodiments, the paste 25 is formulated to continue to harden after the paste leaves the mold cavities 24 as shown in Fig. 1.

[0028] As shown in Figs. 1, 5, and 6, in an embodiment the hopper 26 includes an auger, generally designated 100, that is positioned in the central section 38 of the hopper. The auger 100 may be rotated by a motor 102 and functions to distribute a hardenable paste 25, such as fresh cement paste, along a length of the hopper 26. In an embodiment, the auger 100 is co-extensive with the length of the facing row 28 of the plurality of transverse rows 22 of mold cavities 24. In an embodiment, the auger 100 includes a plurality of radially extending protrusions, generally designated 104, along its length. In an embodiment, the protrusions include radially extending rods 106 and radially extending paddles 108 arranged alternately along a central shaft 110. In an embodiment, the rods 106 and paddles 108 extend radially from the central shaft 110 and are spaced about the periphery of the central shaft. In an embodiment, the central shaft 110 may be rotatably mounted in the end walls 50, 52 of the hopper 26 (see Fig. 2).

[0029] In an exemplary embodiment, the paddles 108 include opposing flat surfaces 112, 114 that are generally planar in shape and are oriented perpendicular, or generally perpendicular, to a central rotational axis of the central shaft 110, which is the same as the central axis of the tubular, rectilinear shaft. The surfaces 112, 114 of the paddles 108, are angled or skewed relative to the central axis of the central shaft 110 to displace fresh cement paste deposited in an end of the hopper 26, along its length, to an opposite end of the hopper when the auger 100 is rotated, for example, clockwise as shown in Figs. 5 and 6. The rods 106 may include beveled ends 116 angled to provide close clearance with the curved inner surface of the hopper 26, in contrast to squared or rounded ends.

[0030] With the auger 100, the hopper 26 may be loaded with cement paste 25 at a loading end 118 (Fig. 2) that may be defined by an enlarged feed chute 119. There is no need to distribute hardenable paste 25, such as fresh cement paste, along the entire width of the open top 32 of the hopper 26. Instead, fresh cement paste may be deposited in only a portion, or in embodiments at a single location, of the hopper 26, for example, into the enlarged feed chute 119, and the auger 100 is rotated by the motor 102 so that the angled paddles 108 rotate in the paste to urge and distribute the paste along the length of the hopper 26, whereupon it falls into the mold cavities 24 of the drum 14 through an opening 120. In an embodiment, the opening 120 is continuous along the length of the hopper and is formed in the bottom panel

122 of the hopper 26. In other embodiments, the opening takes the form of spaced slots 120 that are shaped and aligned with the mold cavities 28.

[0031] In an embodiment, the paddles 108 may be distributed along the length of the auger 100 and may be attached to the central shaft 110 at regularly spaced intervals. Also in an embodiment, the paddles 108 may be positioned along the length of the central shaft 110 so that they are aligned with opening or slots 120 formed in the bottom panel 122 of the hopper 26 as shown in Fig. 6. As shown in Figs. 5 and 6, the paddles 108 and rods 106 may arranged in alternating relation along the length of the central shaft 110. In other embodiments, the paddles 108 may be angled to urge the paste from the center of the hopper 26 outwardly to both sides or opposite ends of the hopper. With such an embodiment, paste may be deposited in a central region of the hopper 26—that is, midway or approximately midway between the ends 50, 52 of the hopper—and rotation of the central shaft 110 may cause the paddles 108 to urge the paste from the center of the hopper 26 to the ends of the hopper. In still other embodiments, the paddles 108 may be angled to urge paste deposited into the top 32 at any location along the length of the hopper 26, and may be angled to urge the paste toward the ends 50, 52 of the hopper from the point at which the paste is deposited.

[0032] As shown in Figs. 5, 6, and 7, in an embodiment, the hopper 26 includes a bottom panel 122. In an embodiment, the bottom panel 122 has an arcuate shape corresponding to a curvature of the drum 14. In an embodiment, the bottom panel 122 has an opening that takes the form of spaced slots 120 that extend the length of the hopper 26. In an embodiment, the slots 120 may be shaped and positioned to align with the mold cavities 124 of the transverse row 22 of mold cavities (a subset of mold cavities 24 shown in Figs. 4 and 8) of the facing row 28 of mold cavities of the drum 14. In an exemplary embodiment, the slots 120 are separated by dividers 126. In still other embodiments, the slots 120 have the same outer dimensions as at least some of the mold cavities 124 that come into alignment with them as the drum 14 rotates relative to the hopper 26. In other embodiments, the opening takes the form of a continuous, unbroken slot 120 that extends the entire length, or substantially the entire length, of the hopper 26 and is co-extensive with the arrangement of mold cavities 24 (Fig. 2) along the length of the drum 14. In still other embodiments, the opening is sized such that the slot 120 comprises the entire bottom of the hopper, eliminating the bottom panel 122.

[0033] An advantage of placing the slots 120 to align with the mold cavities 124 is that the alignment minimizes waste of the fresh cement paste 25 that is deposited in the hopper 26 by preventing fresh cement paste from being deposited between the mold cavities 124 on the outer periphery of the drum 14. As shown in Figs. 5, 6, and 7, in an embodiment the plurality of slots 120 are arranged in a rectilinear row. In other embodiments, the

slots make a non-linear pattern along, or partially along, the bottom panel 122. Each of the slots 120 may be of the same outer dimensions as the corresponding mold cavity 124 of the facing row of the plurality of rows 22 of mold cavities 24 formed on the outer periphery of the drum 14 that may pass beneath it as the drum 14 rotates.

[0034] As shown in Figs. 1, 2, and 4, in an embodiment the hopper 26 is suspended from the upright supports 90, 92 of the frame 12. As shown in Fig. 2, in an embodiment the system 10 includes adjustable cables or chains 130, 132 that are attached to the upright supports 90, 92 and extend downwardly to be attached to the panel 122 in the bottom of the hopper 26. To maintain the hopper 26 in position directly above the 12 o'clock position of the drum 14, in an embodiment the system 10 includes adjustable cables or chains 134, 136, that are attached at their upper ends to the upper portion 30 of the hopper 26 and extend downwardly to be attached at their lower ends to a transverse support beam 138 of the frame 12.

[0035] As shown in Figs. 1 and 4, in an embodiment the hopper 26 is held in position above the uppermost portion of the drum 14 by adjustable cables or chains 140, 142 that are attached to posts 144, 146 of the frame 12. In an embodiment, the adjustable cables or chains 140, 142 also are lengthened and shortened to maintain the hopper 26 at the appropriate orientation above the drum 14. The clearance between the bottom panel 122 of the hopper 26 and the upper portion of the drum 14 is adjusted by appropriately lengthening or shortening the adjustable chains 130, 132 (see Fig. 2). With this structure, the hopper 26 may be suspended from the frame 12 to "float" above the upper portion of the drum 14, which in embodiments may be at approximately the 12 o'clock position, or in other embodiments, rest on the top of the drum 14 with a pre-set amount of weight force of the hopper.

[0036] The foregoing components of the system 10 for forming a flexible mat provide an efficient operation and minimize the waste produced. The frame 12 may be moved by a separate device, such as a tractor or truck, so that, as the drum 14 rotates to deposit the finished flexible mat 74, the mat material is laid out on the ground 66 as a continuous sheet. In an embodiment, as shown in Fig. 1, a tractor 200, which may take the form of a telehandler, may be connected to the transverse support beam 138 by a cable 202 connected to a ring 204. In that embodiment, the tractor 200 may pull the frame 12 of the system 10 to the left in Fig. 1 over the ground 66, which motion makes the drum 14 rotate in the direction of arrow A, pulling the open mesh 58 from the spool assembly 26, under guide tube 72, over guide member 73, and between the outer periphery of the drum 14 and the underside of the bottom panel 122.

[0037] As the sheet 58 of open mesh, shown partially removed in Fig. 6 for clarity, passes beneath the hopper 26, the hardenable paste 25, which has been deposited into the hopper 26 and distributed by the auger 100 along the length of the hopper, falls through the slots 120 into

the cavities 124 (a subset of the cavities 24 shown in Figs. 4 and 8) to fill the cavities. The sheet 58 of open mesh, which is held against the outer periphery of the drum 14 by the bottom panel 122 and the tension of the mesh being payed out from the spool assembly 56 and the pinch between the bottom of the drum and the ground 66, becomes embedded in the paste held in the cavities 124.

[0038] The combination of the sheet 58 of open mesh and paste is held against the outer periphery of the drum 14 and the paste within the cavities 124, 24 as the transverse row 22 of mold cavities 124 rotate forwardly of the bottom panel 122 by the retaining plate 78. By the time the transverse row 22 of mold cavities 124 rotates beneath the retaining plate 78, the paste has hardened sufficiently to retain its shape as it falls by gravity downwardly from the mold cavities to the ground 66, forming the flexible mat 74 (Fig. 1). Further hardening of the paste into the blocks 76 may occur after the flexible mat 74 has separated from the drum 14 and been laid on the ground 66. The finished flexible mat 74 may thereafter be rolled up and transported to a desired location, where it may then be unrolled to form an erosion barrier.

[0039] After the flexible mat 74 has separated from the mold cavities 24, further rotation of the drum 24 brings the now-empty mold cavities upwardly to again pass beneath the hopper 26 to be overlaid with the sheet 58 of open mesh and receive hardenable paste 25 from the hopper 26.

[0040] In an exemplary embodiment, the system 10 for making a flexible mat 74 includes a form having a plurality of mold cavities 24, a panel 122 having an opening 120, and a frame 12 that adjustably supports the panel above the plurality of mold cavities and aligns the opening with adjacent ones of the mold cavities. The frame 12 spaces the panel above the mold cavities 24 a distance sufficient to receive the sheet 58 of open mesh between the panel 122 and the mold cavities. In the exemplary embodiment shown in Fig. 1, the form is the drum 14 having the plurality of mold cavities 24 formed in its outer cylindrical surface. In embodiments, the opening 120 takes the form of a plurality of slots, as shown in Fig. 6. In embodiments, the panel 122, which is a part of the hopper 26, is adjustably supported above the mold cavities 24 of the drum 14 by adjustable cables or chains 140, 142, and clearance between the bottom panel 122 of the hopper and the upper portion of the drum, and hence the spacing of the panel above the mold cavities, is adjusted by lengthening or shortening the chains 130, 132 as well.

[0041] In an exemplary embodiment of the method for making a flexible mat 74 using the system as described in the previous paragraph, the plurality of mold cavities 24, which may be formed on the drum 14, is provided, and the panel 122 having an opening 120 is provided. The panel 122 is positioned above the mold cavities 24 and the opening 120 is aligned with adjacent or corresponding ones of the mold cavities. In an embodiment, positioning the panel 122 above the adjacent ones of the

mold cavities 24 includes adjusting a height of the panel above the mold cavities to a selected spacing between the panel and the mold cavities using the adjusting chains 130, 132 and 140, 142. A sheet 58 of open mesh is placed between the panel 122 and the mold cavities 24, and a hardenable paste 25 is deposited through the opening 120 and into the mold cavities such that the sheet of open mesh becomes embedded in the hardenable paste over the mold cavities. The hardenable paste 25 is allowed to harden into blocks 76 held together by the sheet 58 of open mesh, thereby forming the flexible mat 74, which in embodiments consists of or comprises a tied block mat. The flexible mat 74 is then removed from between the panel 122 and the mold cavities 24.

[0042] Another embodiment of the disclosed flexible mat forming system, generally designated 300, is shown in Fig. 9. In an exemplary embodiment, all of the components of the system 300 are identical in structure and function to their counterparts described with reference to the system 10, and shown in Figs. 1-8, except as otherwise described. In an exemplary embodiment, the system 300 includes a frame 312 on which is mounted an elongate, rotatable cylindrical drum 314. In embodiments, the drum 314 is rotated by a motor 316, which in embodiments is selected from an electric motor and a hydraulic motor, in which case the system 300 is self-propelled, or assists in propelling itself. In embodiments, the motor 316 rotates the drum 314 in a counterclockwise direction, as indicated by arrow **A** in Fig. 9. In other embodiments, system 300 does not have the motor 316, but instead the drum 314 rests on the ground 66 and rotates in the direction of arrow **A** as a result of friction with the ground from the frame 312 being pulled over the ground, which in Fig. 9 is to the left, as indicated by arrow **B** by tractor 200. In an embodiment, the frame 312 includes a pair of horizontal beams 318, 320 on which the drum 314 is rotatably mounted, for example by an axle, such as a journal bearing 317.

[0043] Similar to the drum 14 shown in, for example Fig. 4, in an exemplary embodiment, the drum 314 includes a plurality of mold cavities 324 that are formed about the outer periphery, or cylindrical outer surface, of the drum. In other embodiments, the mold cavities 324 are arranged in a pattern or patterns on the drum 314. In embodiments, the patterns are selected from a rectilinear, transverse row of the mold cavities, a staggered pattern of the mold cavities, a checked pattern of the mold cavities, a random pattern of the mold cavities, a running bond pattern of the mold cavities, and combinations of the foregoing.

[0044] In embodiments the drum 314 takes the form of an elongated cylinder, and is a form having mold cavities 324. In embodiments, the mold cavities 324 are shaped to receive hardenable paste 25 from the chute 27 from the drum of a concrete transport truck, or from a concrete pump, or from a concrete mixer trailer, all generally designated 310, and form the hardenable paste into blocks 76, which in embodiments may be square at

their base. For example, the mold cavities 24 are shaped to form pyramidal blocks 76 of hardenable paste 25 received from the hopper 26 having square bases $6\frac{1}{2}$ " x $6\frac{1}{2}$ " and $2\frac{1}{4}$ " high, although in embodiments the mold cavities have other shapes and/or dimensions, and varying shapes and/or dimensions. For example, the mold cavities 324 are shaped to form blocks 76 having shapes selected from rectangular, square, hexagonal, octagonal, round, elliptical, irregular, and combinations of the foregoing.

[0045] In an embodiment, the system 300 includes an elongate hopper, generally designated 326, adjacent the drum 314. In an embodiment, the hopper 326 is positioned directly above the drum 314 at the 12 o'clock (i.e., uppermost) position above the ground 66, such that the hopper is positioned above uppermost ones of the plurality of the mold cavities 324. In other embodiments, the hopper 326 is positioned relative to the drum 314 upstream of the 12 o'clock position, for example at the 2 o'clock position, and in still other embodiments, the hopper is positioned relative to the drum downstream of the 12 o'clock position, for example at the 10 o'clock position. In other embodiments, the hopper 326 is positioned adjacent the drum 314 in locations between the 3 o'clock position and the 9 o'clock position.

[0046] In an embodiment, the hopper 326 is shaped to receive a hardenable paste 25 and deposit the hardenable paste into mold cavities 324 facing the hopper. In an embodiment in which the mold cavities 324 are arranged in rectilinear transverse rows, the hopper 326 deposits the hardenable paste 25 along a facing row, such as facing row 28 (see Fig. 7) of the plurality of transverse rows of mold cavities 324. In an embodiment, the hopper 326 is constructed identically to the hopper 26 shown in Figs. 1-7.

[0047] In an embodiment, a sheet 358 of open mesh is supported on the frame 312 and moves with the drum 314. In a particular embodiment, the system 300 includes a support, generally designated 356, which in embodiments takes the form of a spool assembly having a spindle or rotating axle, for supporting a sheet 358 of an open mesh, from a roll 360 on the spool assembly, between the hopper 326 and a row of the plurality of mold cavities 24 facing the hopper. In embodiments, the support 356 includes a pair of posts 362 to which a spindle or axle 363 is attached and extends therebetween. In embodiments, the support 356 is mounted on a rear platform 364 of the frame 312. In an exemplary embodiment, the rear platform 364 is supported above the ground 66 by a pair of rear wheels 68 and a pair of front wheels 70, as shown in Fig. 1 for rear platform 64. In other embodiments, such as illustrated in Fig. 9, the rear platform 364 is part of the frame 312 and is cantilevered rearwardly from, and is attached to the journal bearing 317. In embodiments, the spindle 363 is mounted on the posts 362 for free rotation relative to the support; in other embodiments the spindle is motorized to assist in paying out the sheet 358 of open mesh. In other embodiments, the sup-

port 356 takes the form of a shelf integral with or attached to the frame 312 rearwardly of the drum 314, and the sheet 358 is stored on the shelf in a fan-folded stack.

[0048] In an embodiment, the sheet 358 of open mesh is sufficiently open to allow the hardenable paste 25 to flow from the hopper 326 through it into the mold cavities 324. In embodiments, the open mesh is a sheet of a polymer mesh, for example a bi-axial geogrid material comprised of polyester or polypropylene yarns. An example of such a polypropylene mesh is Fornit 30/30 geogrid manufactured by Huesker Inc. of Charlotte, North Carolina. That mesh has an aperture size of 1.35 x 1.35 inches (35 x 35 mm), a mass per unit area of 7 oz/yd² (240 g/m²), and an ultimate wide width tensile strength of 2,055 lb/ft (20 kN/m). In an embodiment, the sheet 358 of open mesh is fed forwardly, that is, to the left in Fig. 9, where it passes beneath the hopper 326 and above the drum 314, which in embodiments is at the 12 o'clock position relative to the drum.

[0049] A hardenable paste 25 deposited into the open top 332 of the hopper 326, and in an exemplary embodiment falls downwardly through the hopper and into adjacent ones of the plurality of mold cavities 324, where it is retained within the mold cavities. In embodiments, the hardenable paste 25 is a fresh cement paste such as Portland cement, and in a particular embodiment, is 5000 psi., wet-cast Portland cement. In other embodiments, the hardenable paste 25 is selected from concrete, a mixture of Portland cement, sand, and/or gravel, and a polymer.

[0050] The sheet 358 of open mesh becomes embedded in the hardenable paste 25 and the combination of open mesh and paste continues as the drum 314 rotates in the direction of arrow **A** in a downstream direction away from the hopper 326 where the paste hardens and the combination of open mesh and paste leaves the lower portion of the drum 314 as a flexible mat, generally designated 74, of blocks 76 of hardened paste material held together by the sheet 358 of open mesh, also known as a tied concrete (i.e., hydraulic Portland cement) block mat when concrete is used as the hardenable paste 25. A sheet of such a flexible mat 74 is suitable for applying to the ground 66 for purposes of erosion control in such applications as hillsides, and stream, canal, and waterway embankments and beds.

[0051] In an embodiment, the system 300 includes a flexible sheet 302, which in embodiments is a plastic sheet, optionally imperforate, having a non-stick surface and a width the same as, or approximately the same as, the drum 314. In a particular embodiment, the flexible sheet 302 is single wound clear polyethylene film, and in further embodiments is a film composed of 100% virgin butene LLD resin. In embodiments, the sheet 302 has a thickness of 1 mil. In an alternate embodiment, the flexible sheet 302 is reinforced poly sheeting. In an embodiment, the flexible sheet 302 is supported on the frame 312 to move with the drum 314.

[0052] In embodiments, a supply 304 of the flexible

sheet 302 is mounted on the frame 312. In embodiments, the supply 304 is fan folded in a stack, and in other embodiments, the supply of the flexible sheet 302 is in the form of a roll, as shown in Fig. 9. In embodiments in which the supply 304 of flexible sheet in the form of a roll, the support 306 is in the form of a spindle that is rotatably mounted on the frame 312 in front of (i.e., in the direction of movement of the drum 314 along arrow **B**), and oriented parallel to the rotational axis of, the drum. In embodiments in which the supply is in the form of a fan-folded stack, the support is in the form of a shelf mounted on the frame 312.

[0053] In one embodiment, the supply in the form of a roll 304 is mounted on the spindle 306 so that the flexible sheet 302 pays out from the underside of the roll and passes over an idler bar 308 that extends the width of the flexible sheet 302. The idler roller 308 in embodiments takes the form of a roller rotatably mounted on a support 310 that is attached to and extends upwardly from the frame 312, or a static, non-rotating pipe, rod, or bar oriented horizontally and mounted on the support 310. In embodiments, the support 310 is in the form of a pair of upright members attached to the horizontal beams 318, 320 of the frame 312. In embodiments, the idler bar 308 is positioned at or above the 9 o'clock position relative to the drum 314, and the sheet passes over the idler bar so that it passes downwardly along the outer periphery of the drum 314 to a pinch point 311 at the 6 o'clock position relative to the drum, where it is pinched between the drum and the ground 66. In an alternate embodiment, the spindle 306 is positioned where the idler bar 308 is shown in Fig. 9, and the flexible sheet 302 is paid from the top of the supply 304 of the flexible sheet, which is in the form of a roll, downwardly over the outer surface of the drum 314 from the uppermost point of contact down to the pinch point 311.

[0054] In an embodiment, during operation of the system 300 shown in Fig. 9, as the system 300 moves in the direction of arrow **B**, and the drum 314 rotates relative to the ground 66 in the direction of arrow **A**, the flexible sheet 302 is paid off of the supply in the form of roll 304, over the idler bar 308 in the form of a roller, and extends about the outer surface of the drum 314 from the uppermost point of contact (at or above the 9 o'clock position) down to the pinch point 311. Initially, it may be necessary to rotate the roll 304 to remove an initial length of the flexible sheet 302 and feed it under the pinch point 311 before filling the mold cavities 324 with hardenable paste 25. As the drum 314 rotates, the flexible sheet 302 is held against the outer surface of the drum 314 by the tension caused by pulling the sheet tight by the pinch point 311, and the resistance to rotation of the roll 304 on the spindle 306. In embodiments, the spindle 306 includes a clutch or friction engagement that resists rotation to provide a desired level of tension between the roll and the pinch point 311, and to prevent overrunning of the roll.

[0055] Thus, the flexible sheet 302 is held against the

outer periphery of the drum 314 and holds the hardenable paste 25 in the molds 324 and the sheet 358 of open mesh against the outer periphery of the drum so that it remains embedded in the hardenable paste as the hardenable paste sets up and becomes dimensionally stable. In an embodiment, the flexible sheet 302 is sufficiently wide to extend the entire width of the drum 314 and cover all of the mold cavities 324. After the hardenable paste 25 has hardened into the blocks 76 of the flexible mat 74, the flexible sheet 302 is separated from the flexible mat as the mat is rolled into the coil 390 shown in Fig. 8.

[0056] In an embodiment, the system 300 optionally includes a shield segment 378 that is mounted on the frame 312 and is positioned adjacent the drum 314 upstream of the point of initial contact between the flexible sheet 302 and the drum. In one embodiment, the shield segment 378 is between the point of initial contact between the flexible sheet 302 and the downstream edge of the hopper 326. In an embodiment, like the retaining plate 78 of Fig. 1, the retaining plate segment 378 is rigid, and in particular embodiments is made of sheet metal such as steel or aluminum, fiberglass, or a relatively thick, reinforced plastic such as nylon. In an embodiment, the shield segment 378 is curved to conform to, and in embodiments have the same curvature and/or center of curvature as, the outer periphery of the drum 314 and is against the outer periphery of the drum to hold the hardenable paste 25 within the mold cavities 324 and the sheet 358 of open mesh against the outer periphery of the drum so that it remains embedded in the hardenable paste within the mold cavities.

[0057] As shown in Fig. 10, a bridge or movable frame 380 includes an upper surface, generally designated 382, which in embodiments is a metal grid, and front and rear supports 384, 386, respectively, which in embodiments are pairs of wheels. The movable frame 380 includes a forward inclined panel 366 and a rearward inclined panel 368. The movable frame 380 optionally includes a substantially horizontal middle panel 370 that interconnects the forward inclined panel 366 and rearward inclined panel 368. In other embodiments, the forward and rearward inclined panels 366, 368 meet to form an inverted "V" shape without the middle panel 370. In an embodiment, each of the panels 366, 368, 370 is comprised of a pair of longitudinally extending parallel beams, such as I-beams, that support a flat panel between them, which in embodiments may take the form of spaced parallel bars or rods extending transversely between the beams. In an embodiment, the movable frame 380 is constructed as shown in commonly owned U.S. Pat. No. 10,161,094, the entire contents of which are incorporated herein by reference.

[0058] In an embodiment, the process for making the sheet of flexible mat 74 further includes lifting the flexible mat 74 from the ground 66 away from the flexible sheet 302, after the hardenable paste 25 has solidified into blocks 76, and placing the mat on the upper surface 382 of the movable frame 380, as shown in Fig. 10. The mov-

able frame 380 is then moved in the direction of arrow C beneath the flexible mat 74, which remains substantially horizontally stationary, so that successive portions of the mat slide over the upper surface 382 and are lifted up over as the movable frame is propelled beneath the sheet of the flexible mat 74, which in embodiments is by a motor (not shown) integral with the movable frame, or propelling the frame by a tractor. This lifting of the flexible mat 74 over the angled intersections of the forward, rearward, and middle panels causes the mat to flex about a transverse axis. This flexing causes debrittlement of the flexible mat 74, in which excess paste that may have flowed beyond the mold cavities 324 during the molding process is broken off from the blocks 74 and falls in the form of shards or chips 372 downwardly from the upper surface 382.

[0059] In an embodiment, the process for forming flexible mat shown in Fig. 9 results in a flexible mat 74 that lies on top of the flexible sheet 302. With the process of debrittlement shown in Fig. 10, the flexible mat 74 is separated from the flexible sheet 302 as it is lifted over the upper surface 382, and the flexible sheet remains on the ground 66 below the movable frame 380. In an embodiment, the chips 372 fall down from the upper surface 382 onto the upper surface of the flexible sheet 302. In an embodiment, the flexible mat 74 is subsequently rolled into a coil 390, as shown in Fig. 8, and the coil transported to a site where needed. In an embodiment, the flexible sheet 302 also is rolled into a coil, thus capturing the chips 372, and disposed of.

[0060] The embodiments shown and described provide an efficient and cost-effective system and method for forming a tied flexible mat 74. The components of the systems 10, 300 are relatively low cost and are capable of producing high volumes of flexible mat 74. While the methods and forms of apparatus disclosed herein constitute preferred forms of the disclosed flexible mat forming system, it is to be understood that the system and invention are not limited to these precise forms apparatus and methods, and that changes may be made therein without departing from the scope of the disclosure.

Claims

1. A system (300) for forming a flexible mat (74) having a sheet of open mesh (358) embedded in and interconnecting a plurality of blocks (76) of a hardened paste, the system **characterized by**:

a rotatable drum (314) having a plurality of mold cavities (324) about an outer periphery thereof that receives a hardenable paste;
 a sheet of open mesh (358) that is fed over the mold cavities so that the sheet of open mesh is embedded in the hardenable paste deposited in the mold cavities; and
 a flexible sheet (302) that is placed against the

outer periphery of the drum over the mold cavities containing the hardenable paste and the sheet of open mesh of the rotating drum to retain the hardenable paste within the mold cavities and retain the sheet of open mesh embedded in the hardenable paste as the hardenable paste solidifies to form the flexible mat.

2. The system as claimed in claim 1, wherein the flexible sheet (302) is a plastic sheet having a non-stick surface facing the mold cavities, and a width approximately equal to a width of the drum.
3. The system as claimed in claims 1 or 2, wherein the flexible sheet is placed against the outer periphery of the drum between a 9 o'clock position and a 6 o'clock position relative to the drum.
4. The system as claimed in any of claims 1 through 3, further **characterized by** a frame (312), wherein the rotatable drum (314) is attached to the frame, and a supply (360) of the sheet (358) of open mesh and a supply (304) of the flexible sheet (302) are supported on the frame.
5. The system as claimed in any of claims 1 through 4, further **characterized by** an idler bar (308) positioned at or above a 9 o'clock position relative to the drum (314).
6. The system as claimed in claim 5, wherein the flexible sheet (302) extends over the idler bar (308) and downwardly over an outer periphery of the drum (314).
7. The system as claimed in any of claims 4 through 6, wherein the flexible sheet (302) extends from the supply (304) to a pinch point (311) at a six o'clock position on the drum (314).
8. The system as claimed in any of claims 4 through 7, further **characterized by** a hopper (326) for receiving the hardenable paste (25) and depositing the hardenable paste into the mold cavities (324) along a length of the drum (314).
9. The system as claimed in claim 8, further **characterized by** a support (356) mounted on the frame (314), wherein the sheet of open mesh (358) is fed from the support to a location between the hopper (326) and the mold cavities (324) facing the hopper.
10. The system as claimed in any of claims 1 through 9, further **characterized by** a rigid shield segment (378) positioned adjacent the drum (314) upstream of a point of initial contact between the flexible sheet (302) and the drum.

11. A system (300) for forming a flexible mat (74) having a sheet of open mesh (358) embedded in and inter-connecting a plurality of blocks (76) of a hardened paste, the system **characterized by**:

a frame (312);
 a cylindrical drum (314) rotatably mounted on the frame and contacting the ground (66), the drum having a plurality of mold cavities (324) about an outer periphery thereof that receive a hardenable paste (25);
 a sheet (358) of open mesh that is carried on a support (356) mounted on the frame, the sheet of open mesh fed over the mold cavities so that the sheet of open mesh is embedded in the hardenable paste deposited in the mold cavities; and
 a flexible sheet (302) that is carried on a roll (304) mounted on the frame, the sheet placed against the outer periphery of the drum over the mold cavities containing the hardenable paste and the sheet of open mesh and extending downwardly to a pinch point (311) between the drum the ground (66) to retain the hardenable paste within the mold cavities and retain the sheet of open mesh embedded in the hardenable paste as the hardenable paste solidifies to form the flexible mat.

12. A method for forming a flexible mat (74) having a sheet of open mesh (358) embedded in and inter-connecting a plurality of blocks (76) of a hardened paste, the method **characterized by**:

rotating a drum (314) having a plurality of mold cavities (324) about an outer periphery thereof;
 depositing a hardenable paste (25) in the mold cavities;
 feeding a sheet of open mesh (358) over the mold cavities so that the sheet of open mesh is embedded in the hardenable paste deposited in the mold cavities; and
 placing a flexible sheet (302) against the outer periphery of the drum over the mold cavities containing the hardenable paste and the sheet of open mesh to retain the hardenable paste within the mold cavities and retain the sheet of open mesh embedded in the hardenable paste as the hardenable paste solidifies to form the flexible mat.

13. The method as claimed in claim 12, further **characterized by** separating the flexible sheet (302) from the flexible mat (74).

14. The method as claimed in claim 13, wherein separating the flexible sheet (302) from the flexible mat (74) includes lifting the flexible mat away from the flexible sheet to allow chips (372) of the hardenable

paste to fall downwardly onto the flexible sheet (302).

15. The method as claimed in claim 14, wherein lifting the flexible mat away from the flexible sheet includes passing a movable frame (380) beneath the flexible mat (74) and over the flexible sheet (302).

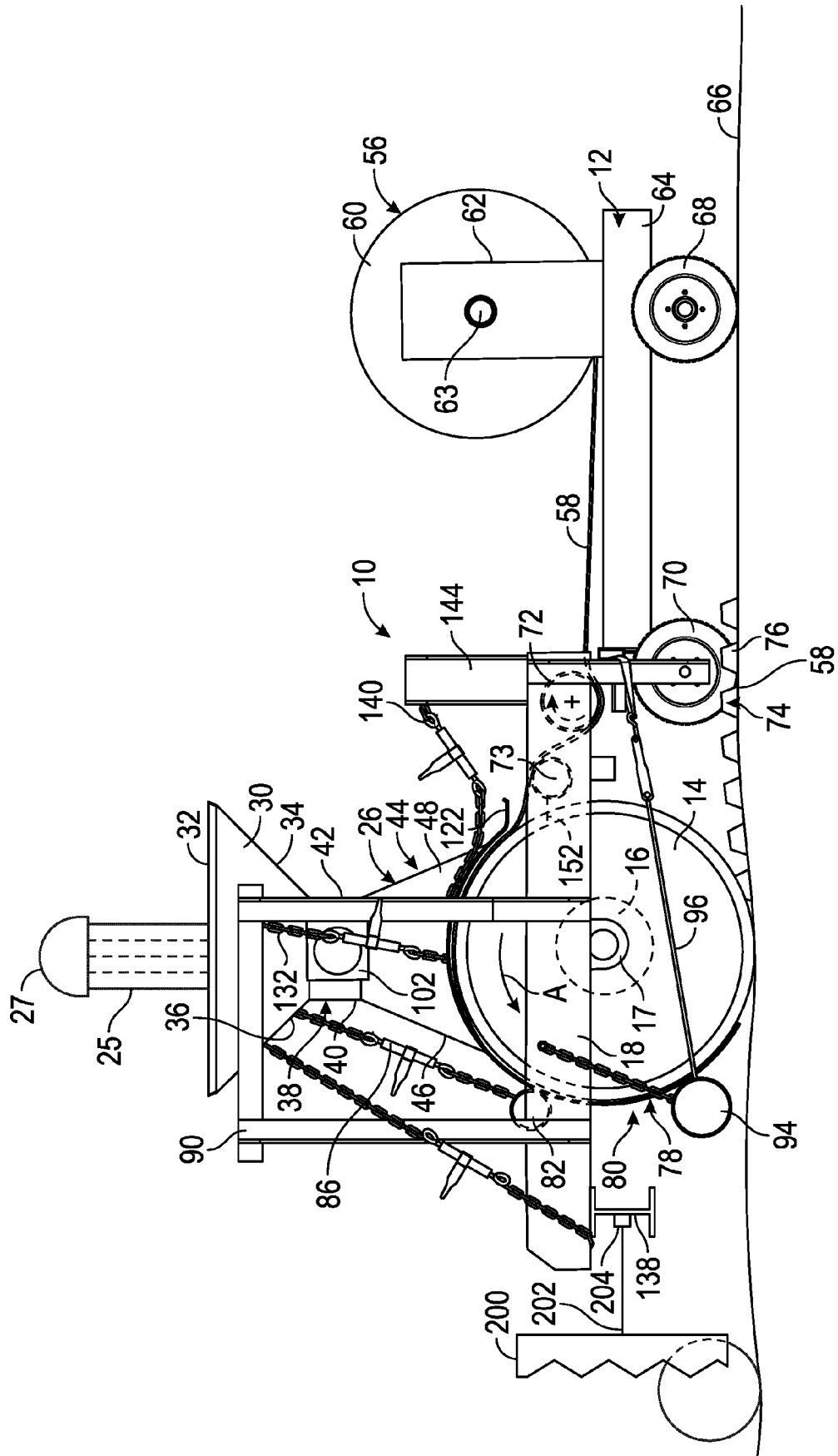


FIG. 1

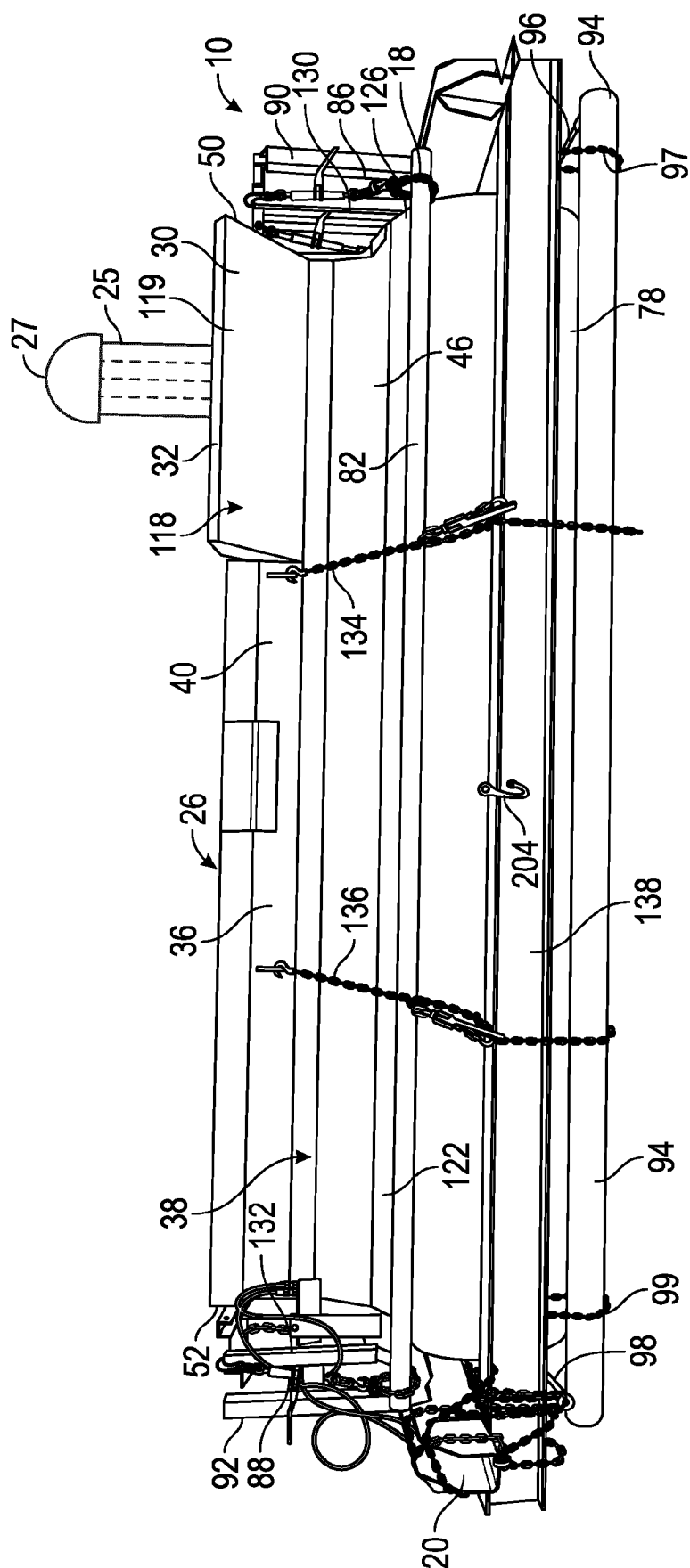


FIG. 2

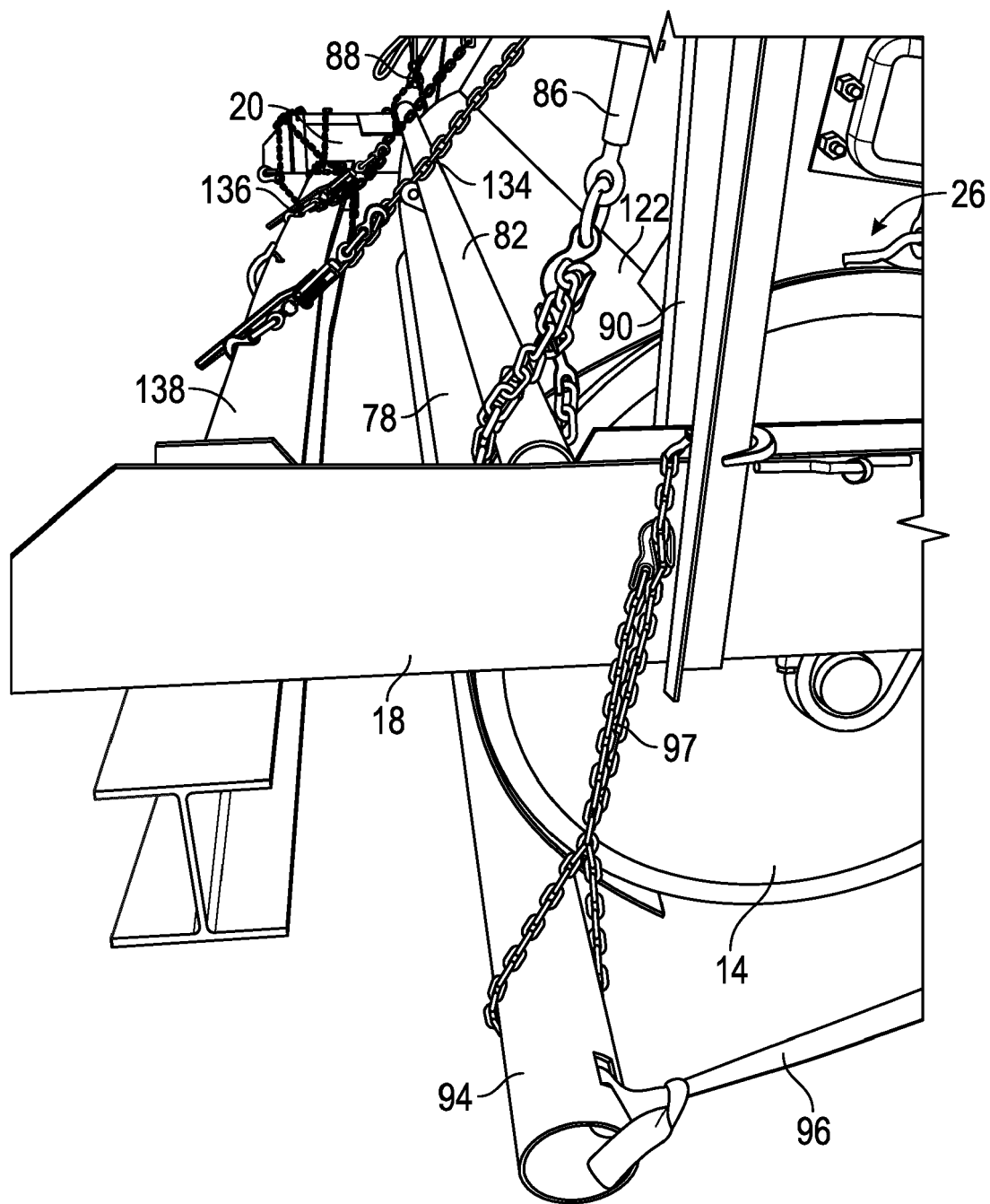


FIG. 3

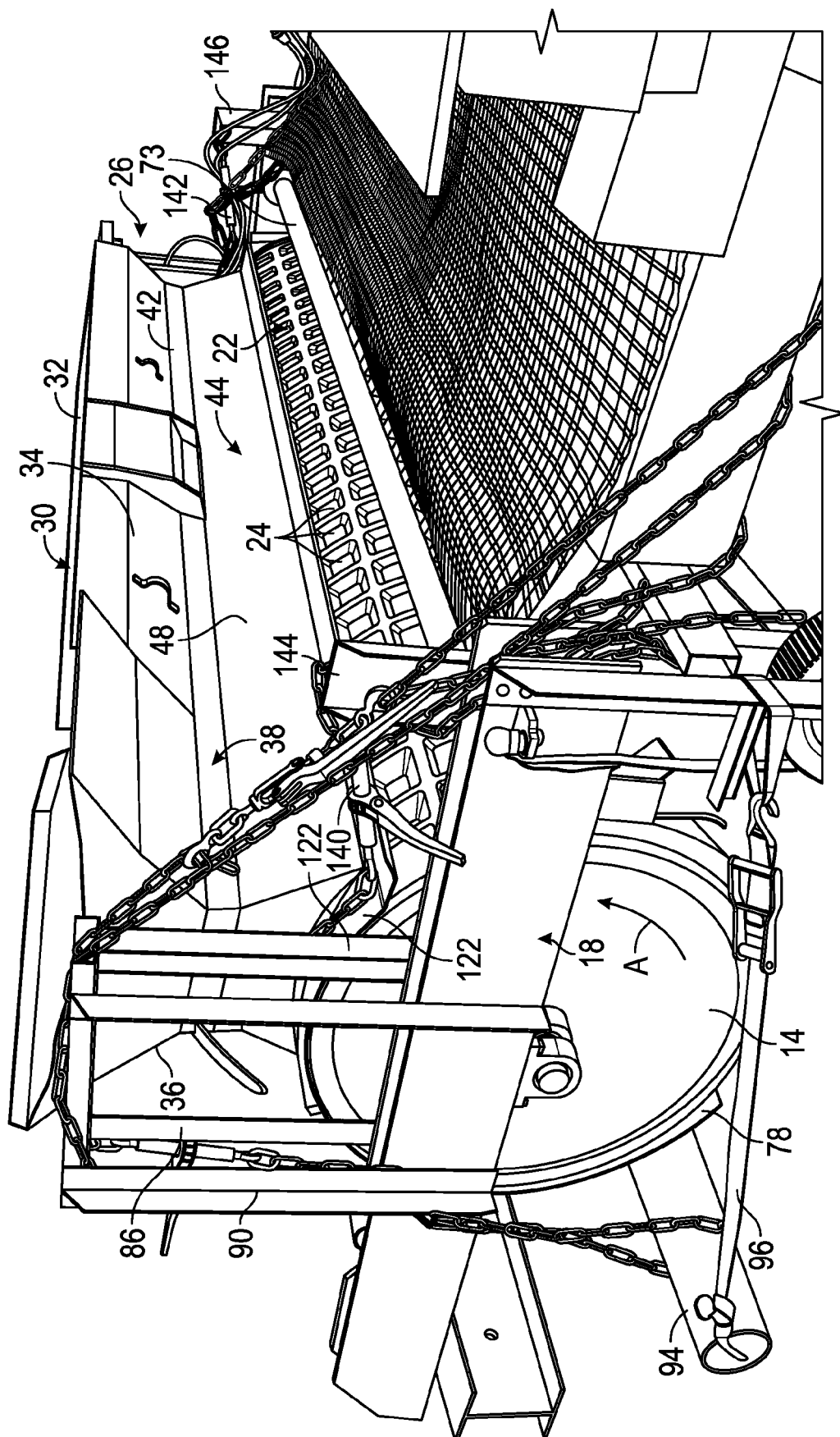


FIG. 4

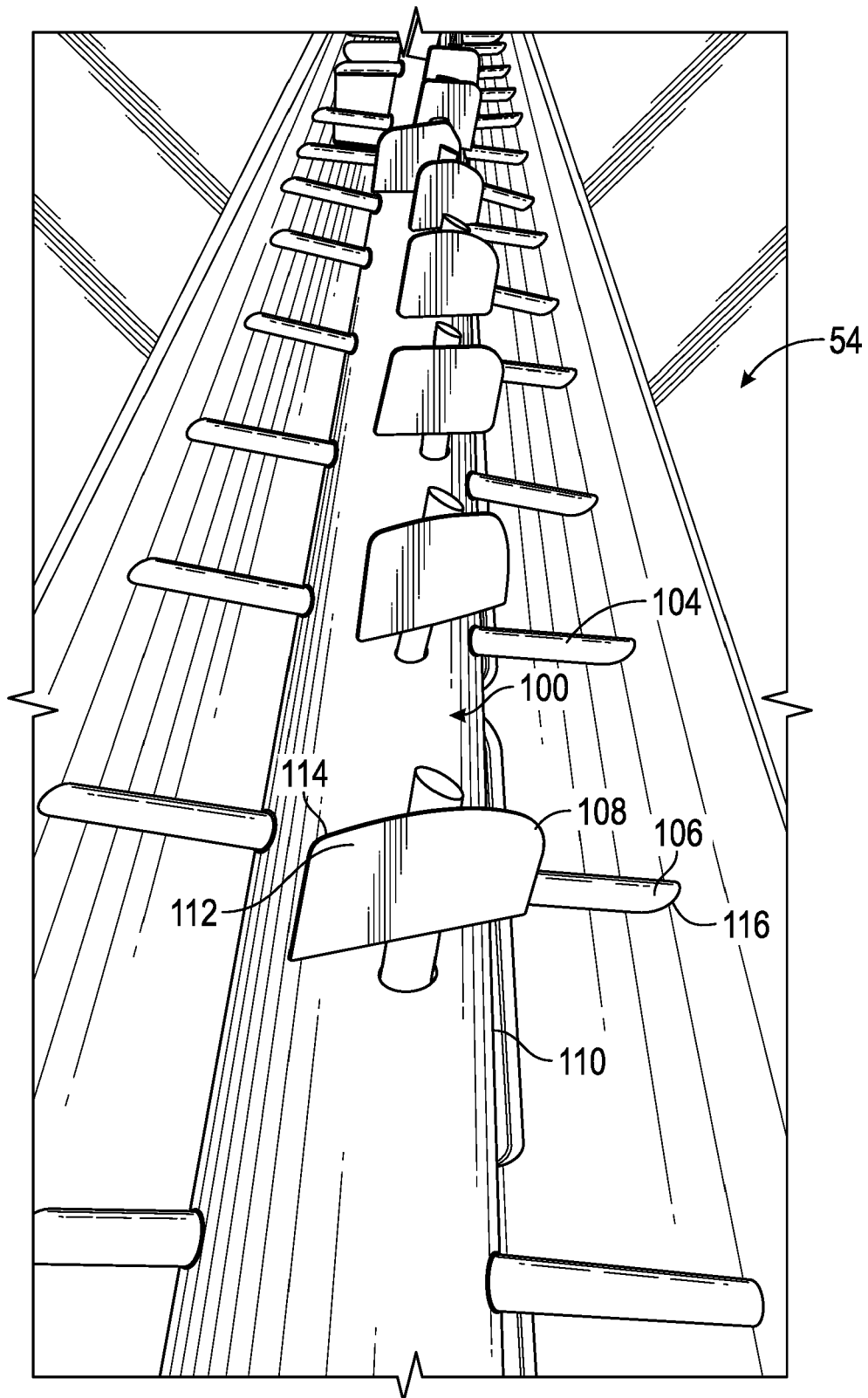


FIG. 5

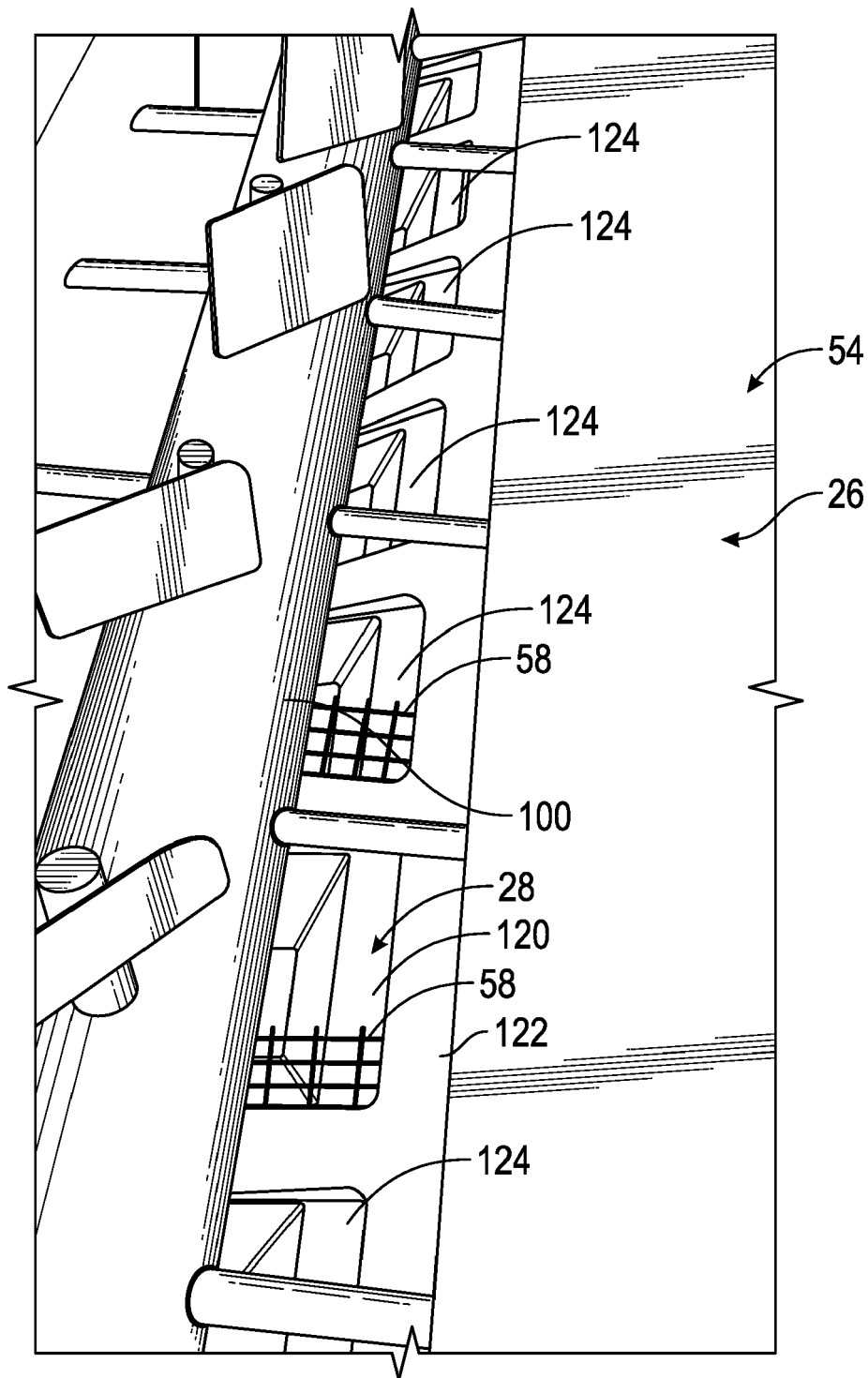


FIG. 6

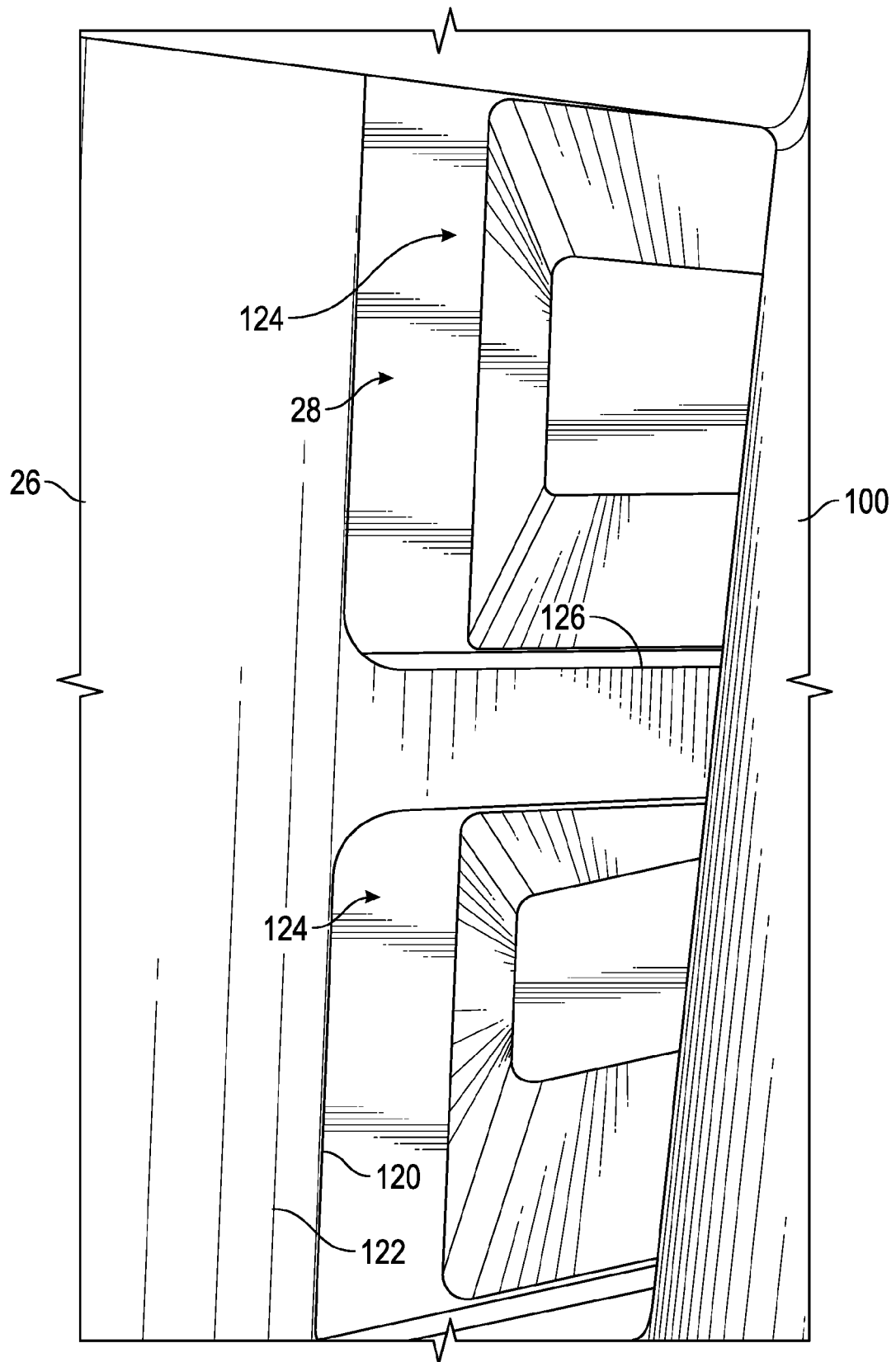


FIG. 7

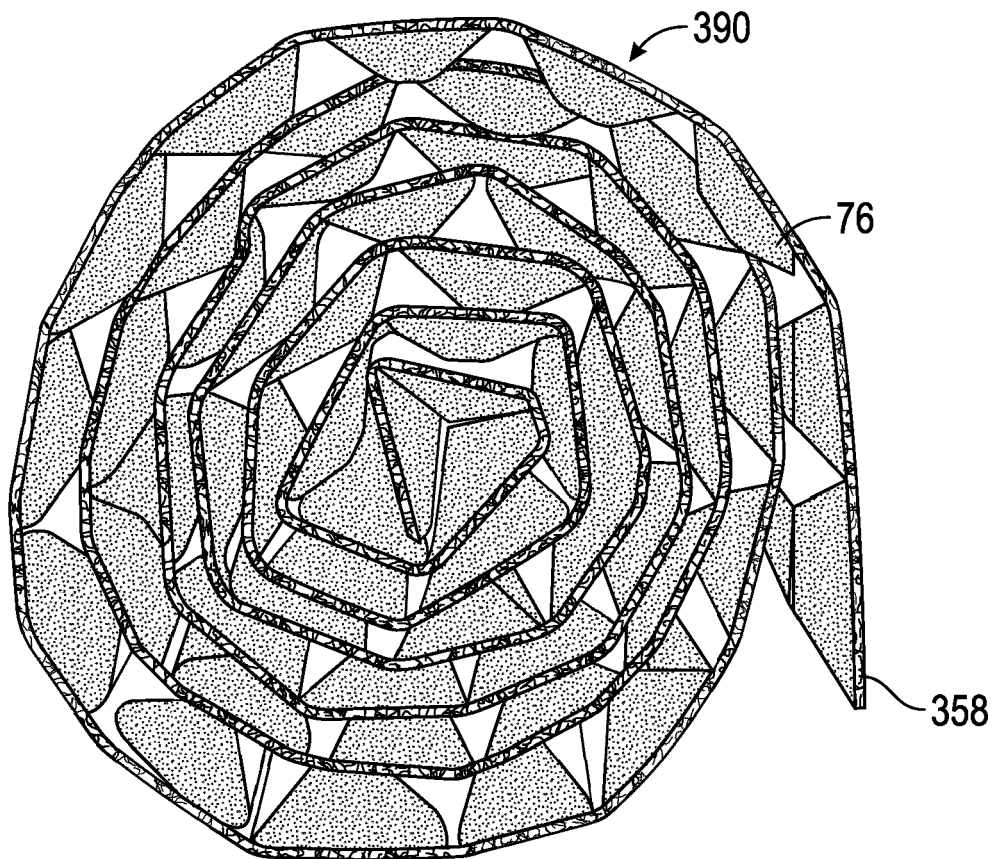
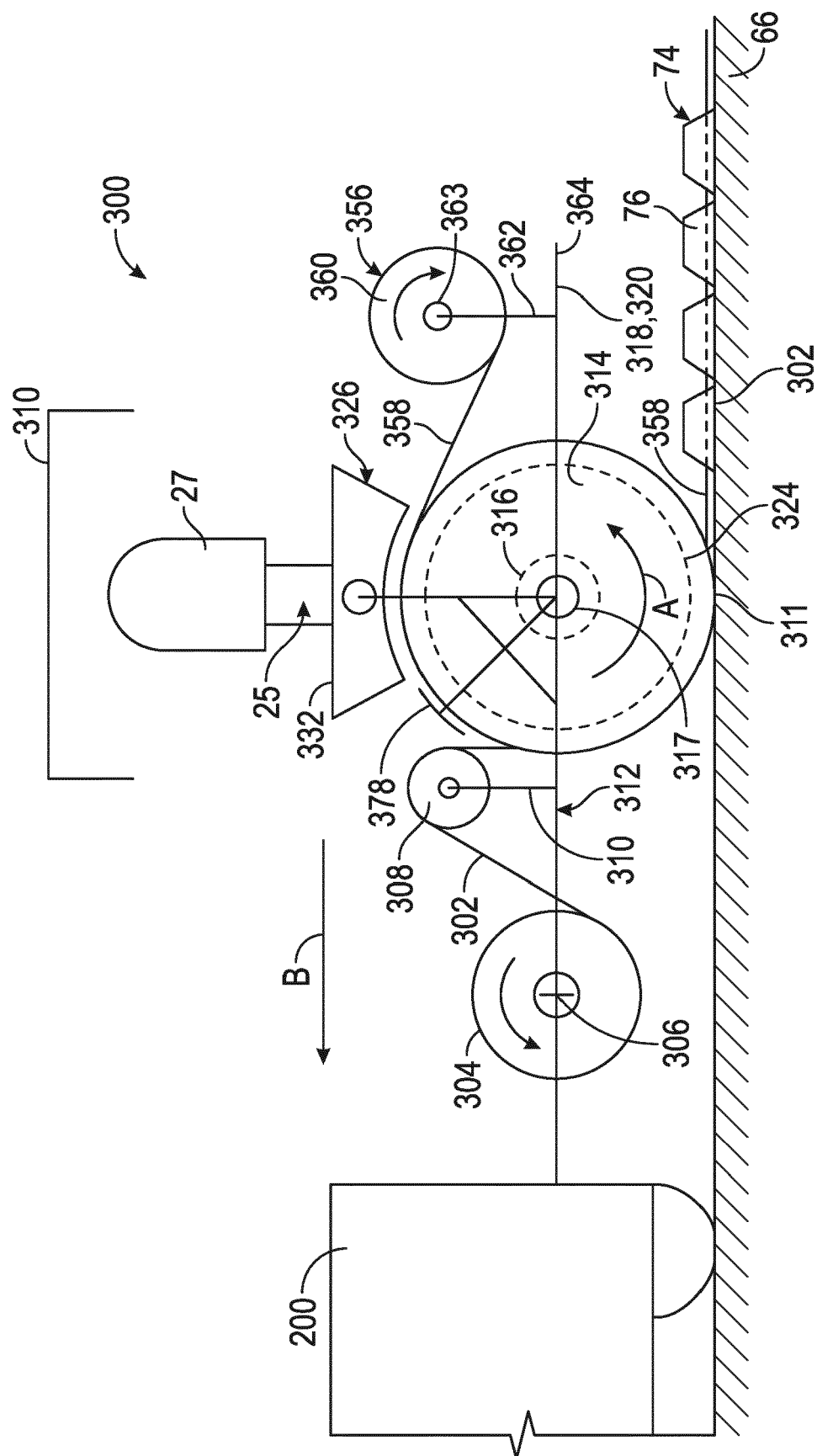


FIG. 8



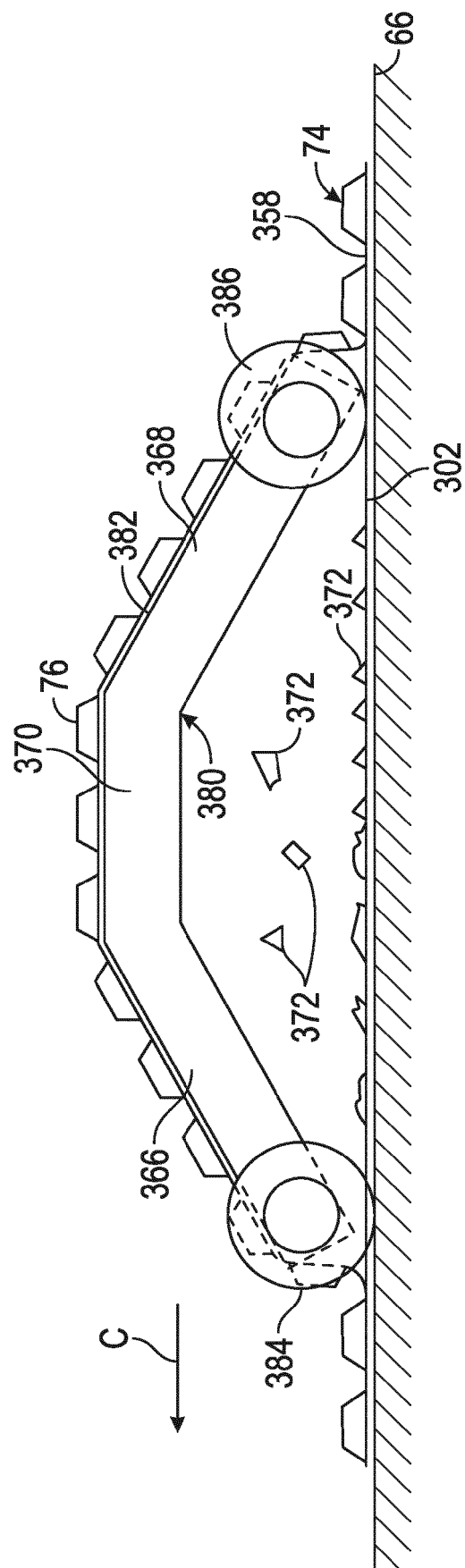


FIG. 10



EUROPEAN SEARCH REPORT

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