

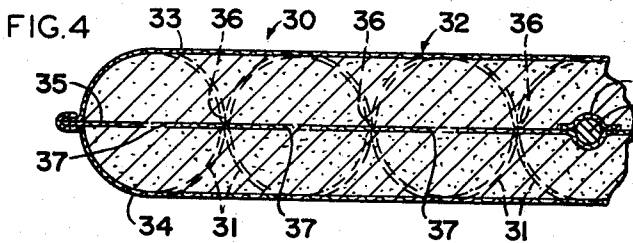
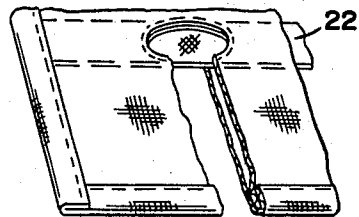
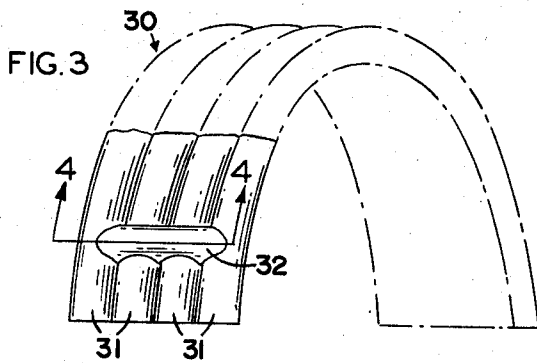
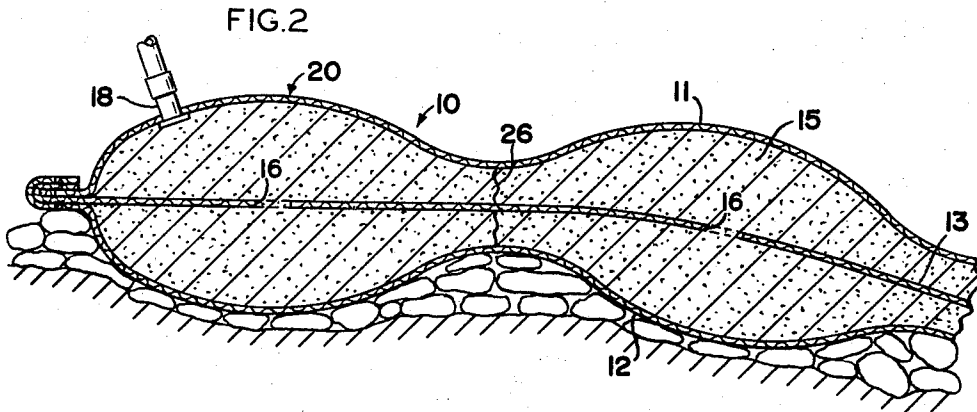
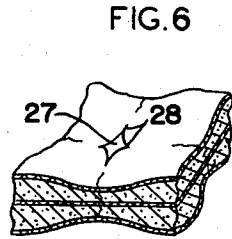
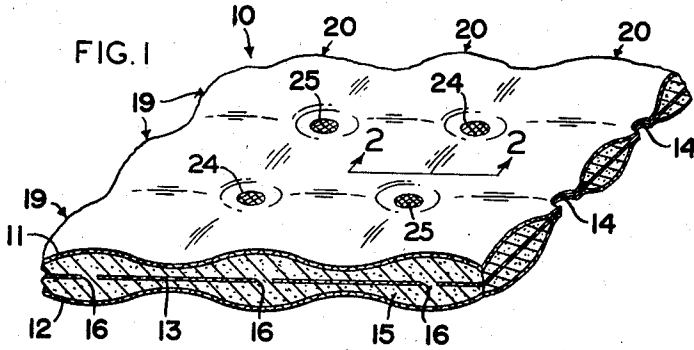
Feb. 4, 1969

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3,425,228

FABRIC FORMS FOR CONCRETE STRUCTURES

Filed Oct. 10, 1967



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FABRIC FORMS FOR CONCRETE STRUCTURES
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Filed Oct. 10, 1967, Ser. No. 674,289

U.S. Cl. 61-38

12 Claims

Int. Cl. E02b 3/12

ABSTRACT OF THE DISCLOSURE

Two continuous sheets of flexible fabric material, at least in part porous, are joined around their entire outer periphery. A third fabric layer is interposed between the two sheets with the three sheets being joined at spaced points to form a plurality of tubes or pockets into which a cementitious slurry is pumped. The third layer of fabric has openings to facilitate the passage of the slurry between upper and lower surfaces of the third layer.

Disclosure

This invention relates to the art of forming cement structures and more particularly to a form useable in forming such structures.

There is disclosed in my co-pending patent application Ser. No. 446,346 a process of manufacturing concrete bodies by constructing forms of water permeable fabric, injecting into these forms a pumpable cementitious slurry, applying pressure to the slurry after the form has been filled, and continuing to hold pressure on the slurry for a brief period of time until substantial amounts of the vehicle water have been forced through the fabric leaving the particles of the slurry behind. This reduces the water content of the slurry which results in rapid stiffening of the slurry and substantial increase of strength at early ages over that which would have been obtained had the water content not been so reduced. Moreover, this process permits use of a slurry having a higher liquid-cement ratio than would otherwise be possible, thus facilitating the pumping of slurry.

Another co-pending patent application, Ser. No. 493,144, describes the manufacture of protective structures for beaches and the like in which two layers of fabric are joined together at suitable spaced places to form a mattress type or interlocking tube configuration. A pumpable cementitious slurry is forced in between the fabric layers in the manner described in the first application.

In carrying out the processes described in these two applications, it has been found that the structures produced have excellent compressive strength as anticipated, but they do not possess desirable resistance to failure in tension. It has also been found that some difficulty has been encountered in positioning the fabric forms under field conditions.

Essentially, these fabric forms consist of a series of envelopes composed of two layers of fabric, an upper surface and a lower surface, joined together at their edges and at suitable intervals therebetween. When slurry is forced into these envelopes, the sides of the envelopes are forced apart and the edges are drawn together laterally. Where the fabric forms consist of a great many interconnected envelopes, appreciable movement of the outermost envelopes will tend to occur. This tendency is resisted, however, by gravity or by the sliding friction of the slurry-filled envelopes against supporting structures such as artificial supports or the surface of the earth. So great is this resistance that in many cases it is impossible to inflate fully the fabric envelopes. In order to avoid development of this resistance, it is possible to preposition the fabric

envelopes, gathering and placing them in such a way that they will inflate fully in place with little or no lateral movement. It is extremely difficult, however, to preposition a large area of fabric in this way under field conditions. In the case where fabric envelopes are to be used to form protective structures for beaches, where fabric must be placed under flowing or wave disturbed water, pre-positioning of the fabric is completely impossible.

The problem of deficient tensile strength may be overcome, as suggested in my co-pending applications, by incorporating reinforcing steel in the structural concrete bodies. However, the assembly of reinforcing steel within the fabric envelopes before injection of the cementitious slurry has been heretofore time consuming and expensive. The fabric may also be damaged by the steel during the assembly process. In the case of beach protective structures, inclusion of steel reinforcing rods within the fabric envelopes causes the completed structure to span underlying depressions in the soil rather than conforming closely to irregularities of the soil surface as is desired.

Furthermore, and directed specifically to the manufacture of protective structures for beaches and riverbanks, a finished structure is desired which will articulate or readjust itself to movement of underlying soil as might be caused by subsidence of the soil under load or movement of soil due to the action of the water as may occur at the exposed edge of a beach protective structure.

All of the problems which have arisen in connection with commercial application of the construction methods described in my co-pending applications may be overcome by employing the form assembly which is the subject of this invention. In its broadest aspect the invention contemplates a form comprising two large continuous sheets of flexible material which are, at least in part, porous. The sheets are joined around their outer periphery and have a plurality of tie points joining the two sheets intermediate their edges to form a plurality of envelopes. A third piece of fabric is interposed between the two sheets with the third piece of fabric being secured to the outer periphery of the sheets.

It is preferred that the third piece of fabric comprise a sheet which has less area than either of the two outer sheets and which is located approximately midway between the upper and lower surface fabrics, with the third sheet having openings to permit the slurry to pass from the upper side of the third piece of fabric to the lower. Alternatively, this third piece of fabric may comprise either a plurality of substantially parallel strips of fabric which extend between the two surface fabrics on the center lines of the tie points or a lattice network of intersecting strips intermediate the tie points.

A form such as that disclosed herein has several advantages. First, it facilitates the positioning of the envelopes in their finally inflated or slurry-filled position. Secondly, this third layer of fabric acts as a hinge to permit articulation of the mattress when it is being used as a beach-protective structure.

Thirdly, this third layer of fabric provides substantial tensile reinforcing, in addition to that already provided by the two surface fabrics. The surface fabrics, when first installed, may be of such quality as to provide necessary tensile reinforcement. However, the surface fabrics, after installation, are subject to mechanical damage, abrasion, chemical attack, and degradation by ultra-violet light, and so reliance cannot be placed on them to provide permanent tensile reinforcing. Interior fabric, by contrast, is completely protected from these damaging forces. Additionally, bending forces on the hardened structure place tensile stresses on the surface fabric which increase in direct proportion to the thickness of the structure. Repeated bending forces may therefore cause failure of a tensile resisting surface fabric, while interior tensile rein-

forcing fabrics are less susceptible to failure. Centrally located fabric is flexed but not tensioned by bending moments.

Finally, this third layer of fabric makes possible the use of flexible reinforcing cable rather than steel rods customarily required in arch or thin shell structures. Structures of this type, when formed and cast in the conventional manner, are normally reinforced with steel rods or bars which are positioned with respect to the form surfaces. When fabric is used as a forming material, it is not convenient to use steel rods which are relatively rigid and tend to damage the fabric. Fabric with rigid steel bars installed cannot be conveniently prefabricated, collapsed, and transported. When a third centrally located fabric layer is incorporated within the fabric assembly, flexible steel cable may be prepositioned on this third layer, so located that when slurry has been injected into the fabric envelope, the steel will be ideally positioned to resist tensile stresses. Furthermore, the entire assembly of fabric and flexible steel cable may be completely and economically preassembled at a convenient factory, collapsed into a compact package, transported to a remote job site, and there be erected with a minimum expenditure of job site labor.

Thus, a principal object of this invention is to provide a form for concrete structures which has enhanced tensile-resisting characteristics and which decreases the cost of forming such structures.

Another object of the invention is to provide a form for cement structures wherein the positioning of the form in inaccessible locations is facilitated.

A further object of the invention is to provide a form for a cement structure which will be subjected to tensile stress and wherein the form itself includes means to assist in resisting the tensile stresses imposed on the completed structure.

Still another object of the invention is to provide a form of fabric material for cement structures which form includes an intermediate layer of fabric embedded in the cement which permits the articulation of the cement structure.

A better understanding of the objects, features and advantages of the invention may be had by referring to the following description and drawings which are presented for illustrative purposes only and not with intent to limit the scope of this invention.

FIGURE 1 is a perspective view of a section of protective beach structure employing the instant invention.

FIGURE 2 is an elevation view through a section of the structure of FIGURE 1.

FIGURE 3 is a perspective view of a shell or arch constructed in accordance with this invention.

FIGURE 4 is a section taken along line 4—4 of FIGURE 3.

FIGURE 5 is a fragmentary section of a modification of the invention.

FIGURE 6 is a view similar to FIGURE 1 showing a modified form of openings in the structure.

Referring now to FIGURE 1, a beach protective structure similar in appearance to a mattress is generally indicated by the reference numeral 10. The mattress 10 is constructed of three layers of fabric, an upper layer 11, a lower layer 12, and a third layer 13, positioned generally midway between layers 11 and 12. These three layers are joined together at tie points 14 located at suitable intervals. The fabric envelope defined by the upper layer 11 and lower layer 12 is then filled with a flowable hardenable cementitious slurry 15. To facilitate filling of the envelope with slurry, it is convenient to provide openings 16 through the fabric 13 in order that the slurry may pass freely from the space between layers 11 and 13 to the space between layers 13 and 12. Alternatively, the fabric 13 may be of a very open construction, such as leno weave or knitted construction which permits the

slurry to pass freely therethrough, thus eliminating the need for forming openings 16.

It is thus necessary to inject slurry through layer 11 or layer 12, but not through both in order completely to fill the fabric envelope. Injection of slurry through the envelope may be most conveniently accomplished by making small perforation or incision in the fabric and forcing therethrough a pipe 18 of an outside diameter slightly larger than the incision. Some of the fibers of the fabric are thus forced apart during insertion of the pipe. As the fabric is tensioned by the outward pressure of injected slurry, the parted fibers tend to draw together around the pipe, gripping the pipe securely by friction and preventing ejection of the pipe from the fabric envelope by back pressure of the injected slurry.

It is also possible to attach the slurry injection pipe to the fabric envelope by means of threaded fittings, inserted through perforations in the fabric and secured thereto by means of locknuts, flanges, or the like, with or without additional fastening means such as screws, bolts, or adhesive. It is also possible to make an oversize incision in the fabric and place the slurry injection pipe therein.

Prior to injection of the slurry, the fabric envelope assembly is laid out on the surface to be protected, which surface may consist of a natural beach, above or below water, a sand dune or earth bank, or an artificial surface such as a mound of soil, rock, shells, or the like which, when adequately protected against destructive forces, may then serve to form a dike, a groin, a breakwater, or the like.

The particular protective structure illustrated in FIGURE 1, although similar to a mattress in appearance, actually consists of two mutually perpendicular series of slurry filled tubes 19, 20 with each tube in each series lying in a parallel spaced relationship. As slurry is injected into the fabric envelope, the envelope tends to shorten in the horizontal direction perpendicular to each tube axis. It also tends to lengthen in the horizontal direction parallel to each tube axis by reason of the fact that the fabric is elastic and therefore lengthens by an amount proportional to the pressure of the injected slurry. The injection of slurry into a series of interconnected and mutually perpendicular tubes thus sets up opposing forces, the net effect of which will be to produce a slurry filled structure, the planar area of which tends to be less than the planar area of the fabric alone before injection of the slurry.

One of the functions of the intermediate fabric layer 13 is to reduce greatly this tendency toward area contraction by prepositioning surface fabric layers 11 and 12 in the position which they would tend to take upon the injection of slurry filling, if the fabric envelope were free to slide on a frictionless horizontal plane. Because of the many complex forces acting on the fabric envelope during slurry injection, it is virtually impossible to dimension such a fabric envelope with mathematical precision. It is therefore necessary to design such an envelope empirically, making allowance for fabric characteristics, spacing and relative orientation of tie points 14, and size and shape of the tie points.

For example, if layers 11 and 12 were to consist of 850 denier high tenacity nylon filament yarn, plain woven at 22 yarns per inch in both filling and warp direction, and if these two layers were attached together to form 1½" square tie points on 8" centers, then a double layer envelope so formed would contact in surface area about 15%. Accordingly, an intermediate fabric layer 13 which is 15% less in area than surface layers 11 and 12 is introduced and is attached to the surface layers at points on the intermediate layer at a spacing, the square of which bears to the square of 8, the ratio of 0.85 to 1.0. The three layers of fabric are thus tied together at a distance equal to $\sqrt{(0.85)8^2}$ or 7.4 inch centers, the distance along the surface of the upper fabric

layer 11 and lower fabric layer 12 being each 8 inches.

The tie points 14 may be of various constructions. One form of tie point may be a screened metal grommet in which the fabric within the grommet area is removed. A wire mesh screen 25 may be inserted in the openings through the grommets or the grommet area may be left entirely open. The tie points also may be openings formed in the fabric with stitching around the periphery of the opening. It is to be understood that tie points of other types of construction may also be employed.

In practice, it may be desirable to vary the theoretical tie point spacing somewhat to provide for a thicker or thinner section of the completed structure. It may also be desirable to provide a greater area of fabric in one of the two outer surface layers 11 and 12 than in the other, for example, to provide for two fabrics with different elasticity. It may also be desirable to provide an intermediate fabric layer, as shown in FIGURE 5, in the form of multiple strips 22 completely separated along parallel lines, the centerlines of the strips being generally located on the centerline of the tie points. A fabric envelope so constructed provides dimensional control during slurry injection only in the direction perpendicular to centerlines of such centrally located fabric strips. A further modification might employ a series of strips perpendicular to strips 22 thus providing dimensional control in both directions. Alternatively, a pre-assembled lattice network of mutually perpendicular strips, interconnected at their points of intersection, may be employed.

When subjected to the erosive forces of nature, such as wind and the action of moving water, supporting soil underlying the beach protective structure illustrated in FIGURE 1, tends to move out from under the structure, either through the opening 24 in the mattress 10 or from beneath the edge of the structure by a process known as scour. The loss of soil creates a void beneath the structure. The weight of the structure itself and, more important, live loads placed upon the structure as by wave action, induce bending stresses in that part of the structure spanning such a void. These bending stresses frequently cause failure of the hardened cementitious slurry 15. Failure is evidenced by cracking of the slurry, or mortar 15, leaving the structure held together only by the tensile resisting fabrics 11, 12 or 13. Since fabrics 11 and 12 are subject to possible damage by erosion, by chemical attack, or by ultra-violet degradation, complete reliance as to permanent structural integrity can only be placed on the interior fabric layer 12 which is permanently protected by the mortar at all times.

This cracking of the mortar 15 is in no way detrimental to the successful performance of the structure as a beach protective device and is, in fact, highly desirable, since the structure is thus permitted to hinge or articulate and so adhere closely to the changing contours of the soil which it is designed to protect. This condition is illustrated in FIGURE 2 wherein cracking of the mortar 15 at 26 has permitted the right side of the structure to move downward into engagement with the underlying soil.

The cracking of the mortar 15 normally occurs in the reduced cross-sectional areas which are generally coincident with the centerline of the tie points. To encourage the cracking of the mortar in these areas, the tie points may be made star shaped in configuration in the manner shown in FIGURE 6. The star shaped openings 27 have points 28 which lie in the plane of the reduced cross-sectional areas of the structure and, in effect, define lead lines extending into the reduced cross-sectional areas between adjacent rows of tubes 19, 20. These lead lines encourage cracking of the mortar and define the path along which the cracking will occur thereby providing more uniform cracking than normally is the case where round tie points are used.

FIGURE 3 illustrates another application for the im-

proved fabric form. Thus an arch, indicated generally by the reference numeral 30 may be composed of a series of mortar filled fabric tubes 31, located in generally a side-by-side relationship. These tubes may be interconnected with one or more transverse tubes 32.

The tubes are composed of an upper or outside fabric layer 33, a lower or inside fabric layer 34 and an interior reinforcing and spacing layer 35, joined at convenient and generally parallel seams 36. By interrupting these seams, the transverse tubes 32 are formed. The intermediate fabric layer 35 will be provided with slits, perforations or openings at convenient intervals to permit free passage of hardenable cementitious slurry from one side of fabric 35 to the other. The fabric assembly is usually designed in such a way that the length of fabric 35, centerline to centerline of seams 36, is equal to the diameter of the semicircle of fabric 33 on one side or fabric 34 on the other side. Interior fabric layer 35 serves the function of pre-positioning the entire fabric assembly prior to injection of slurry and of providing tensile reinforcing within the finished structure in the same manner as the described structure of FIGURE 1. In addition, the fabric layer 35 may serve as a positioning means for reinforcing steel members 39 within the structure. Additional positioning means, as illustrated by tie 40, may be provided to position the members 39.

In the construction of fabric assemblies described herein I may use virtually any fabric and any type of connection of strength adequate to sustain the pressure of injected slurry. In general, I prefer that at least part of the fabric be of sufficient porosity to pass some of the vehicle water from the slurry, reducing thereby the water/solids ratio with attendant increase in the strength of slurries containing portland cement and increase in the rate of stiffening. Fibers should generally be compatible with alkaline solutions, such as portland cement slurries. Abrasion resistance, resistance to ultra-violet degradation, and good bonding to cement mortar is also important. The following are fabric constructions which have proven to be particularly satisfactory in the applications described.

Example 1

Beach protective structure for the banks of a river or canal subject to low to medium stream velocities:

Fabric Position	Warp Material	Warp count (in.)	Fill material	Fill count (in.)
Top.....	850 denier filament nylon.	20	965 denier cordura.	20
Center.....	do.....	18	850 denier filament nylon.	18
Bottom.....	do.....	20	do.....	20

The fabric is tied together on 7" centers measured on the center fabric. Tie points are 1½" circles formed by insertion of metal grommets. An additional 15% surface area is provided in the top and bottom fabrics. All fabrics are plain weave.

Example 2

Beach protective structure for an open beach subject to severe hurricanes:

Fabric position	Warp material	Warp count (in.)	Fill material	Fill count (in.)
Top.....	1,850 den. cordura nylon.	20	1,850 den. cordura nylon.	20
Center 2 layers bas et weave 4/4.	1,050 den. filament nylon.	20	1,050 den. filament nylon.	20
Bottom.....	850 den. filament nylon.	20	850 den. filament nylon.	20

The fabric is tied together on 16" centers measured on the center two fabric layers. Tie points are 4" circles formed by insertion of screened metal grommets. An additional 20% surface area is provided in the top fabric. An additional 15% surface area is provided in the bottom fabric. All fabrics plain weave except as noted.

Example 3

Tunnel structure for the purpose of installing a lining within a bore hole is fractured rock with heavy water inflow:

Fabric position	Warp material	Warp count (in.)	Fill material	Fill count (in.)
Outside neoprene coated 1/16"	965 den. cordura nylon.	20	965 den. cordura nylon.	20
Center.....	850 den. filament nylon.	20	850 den. filament nylon.	20
Inside.....	965 den. cordura nylon.	20	965 den. cordura nylon.	20

The fabric is joined together by parallel seams, 6" center to center measured on the center fabric, seams being interrupted for a distance of 6", interruptions being 15° apart along the arc of the lining. Each of the circumferential tubes and each of the transverse tubes are reinforced with 1/2" plow steel cable, centrally positioned within the fabric tube by attachment to the center fabric layer. Additional fabric is provided for the outside and inside fabric layers so that the distance along the fabric measured from seam to seam perpendicular to the tube axis equals $\pi/2$ (6"), approximately, but the length of outer and inner fabric measured parallel to the tube axis is the same as the length of the center fabric in this direction.

Any flowable hardenable slurry may be used as a filling material for these fabric forms. In practice, a mix which bleeds or segregates rather easily is preferred. Following are examples of mixes which have proven to be satisfactory in the applications described.

Example 1

Beach protective structure for the banks of a river or canal subject to low to medium stream velocities:

Cement	Lbs. 94
Silty sand	560
Water	70

Example 2

Beach protective structure for an ocean beach subject to severe hurricanes:

Cement	Lbs. 94
Fly ash	25
Concrete sand	170
Calcium lignin sulfonate	0.25
Water	58

Example 3

Tunnel structure for the purpose of installing a lining within a bore hole in fractured rock with heavy water inflow:

Cement, Type III	Lbs. 94
Concrete sand	94
Water	42

It will be appreciated that the structure thus described provides an improved form which overcomes many of the problems heretofore experienced with similar forms. The specific examples described are intended to be merely illustrative of some of the applications for the improved form. In general, the described form has particular application to construction which will be subjected to tensile stresses and to situations in which the positioning of the form normally is difficult to accomplish.

Having thus described my invention, I claim:

1. A form for cement structures comprising two large continuous sheets of flexible material at least in part porous; said sheets being joined around their entire outer periphery; an intermediate layer of flexible material interposed between said two sheets; said intermediate layer extending across said two sheets and being secured to the outer periphery of said two sheets; and means interconnecting said two sheets at least at spaced intervals throughout the length and width of said form.
2. The form of claim 1, wherein said intermediate layer comprises a third sheet; said interconnecting means joining said third sheet to said two sheets.
3. The form of claim 2, wherein the area of said third sheet is less than the area of either of said two sheets.
4. The form of claim 2, wherein said third sheet includes openings formed therein to provide access between the upper and lower surfaces of said third sheet, said openings being spaced from said interconnecting means.
5. The form of claim 1, wherein said intermediate layer comprises a plurality of separate strips of material.
6. The form of claim 1, wherein said interconnecting means comprise a plurality of substantially parallel seams.
7. The form of claim 6, wherein said seams are discontinuous at predetermined points along the length thereof.
8. The form of claim 1 and further including reinforcing means supported on said intermediate layer.
9. The form of claim 2, wherein said interconnecting means include openings passing through the three sheets.
10. The form of claim 9 wherein said openings are star shaped in configuration.
11. The form of claim 1 wherein said interconnecting means comprises star shaped openings through said two sheets.
12. The form of claim 5, wherein said strips are connected to said sheets by said interconnecting means.

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PETER M. CAUN, Primary Examiner.