The invention herein described pertains broadly to a continuous plaited structure formed from bendable materials and adaptable in its several embodiments to numerous functions in the form of panel or broad structures, which exhibit a quality of unusual rigidity in comparison to conventional utilization of like materials. The structure is capable of being formed of paperback and incorporated with one or with more planar sheets to form composite structures corresponding in general to conventional singleface and doubleface corrugated fibreboard.

Among other forms contemplated by the inventors, in addition to paperback, is a structure of thin, lightweight bendable metal. This may include a plurality of superposed plaited sheet, with interposed sheets having an essentially planar characteristic in relation to the plaited and brazed or welded therein. It is thus adapted for utilization in aircraft and other purposes where rigidity and light weight are essential characteristics.

The plaited member comprises integral parallel V-shaped flutes having alternately folded planar sheets in equispaced relation. The transverse fold lines forming the sharp apexes of the plait have novel indentations at spaced intervals. The indentations being characterized by pairs of spaced apart parallel sides at right angular relation to the fold lines and an integral truss member spaced from the apex margin of the flutes, integral with and connecting the converging sides of a plait. This novel indentation of the apexes of the plait in providing the particular truss formation immobilizes the planar sides of the flutes in the predetermined angular relation and imparts unexpected load carrying capacity to the structures as well as resistance to lateral deflection or distortion.

Conventional corrugated paperboard is of course well known in its many variations and modifications. Basically the known corrugated structures are based on an arcurate undulated intermediate sheet or corrugated medium. In the most common form, as practiced in the corrugated medium is adhesively secured in flatwise relation at the extremities of the undulations or flutes to facing sheets commonly termed liners. For most purposes it is desirable to secure such liners to both sides of the corrugating medium but to a lesser extent it has been a well known practice to use a composite paperboard comprising an undulated corrugating medium and a single facing sheet secured on one side thereof. In these forms, with the undulations or corrugations retained in equally spaced relation by the means of the facing sheets or liners, conventional corrugated board has substantial and well known utility. However, the undulated type corrugating medium of and by itself and in the absence of the described liners has little utility having negligible resistance to crushing forces or to lengthwise deflection in contrast to the present invention.

The plaited sheet of V-shaped flutes with planar walls, indentations at uniformly spaced intervals along the apexes of the flutes with a horizontal truss member at the base of the indentations integral with the converging walls of the flutes, constitutes an improved principle of construction. The formed sheet, as such, without liners, is remarkably rigid, has a substantial load carrying capacity, is substantially proof against lengthwise distension and has utility for many purposes.

Other advantages, absent in the conventional corrugated medium, directly attributable to the new and novel plaited medium includes the substantial elimination of "spring back," which simplifies and facilitates attaching the liners. Further, the truss members tend to reduce the effective column height of the flute walls, which in turn increases the crushing resistance of the plaited structure in comparison to conventional corrugated boards and thereby reduces the usual deleterious effects encountered such as impaired rigidity, support and protection. It has been determined both by mathematical means and by physical testing that an improvement in flat crush resistance on the order of 19 percent over conventional corrugated board constructed of like materials may be expected.

The greatly increased load carrying capacity and resistance to lengthwise deflection of plaited sheets hereinbefore set forth for composite structures of paperboard compared with conventional corrugated paperboard, inures to the novel plaited sheets of the present invention formed of relatively thin, light weight, bendable metal compared with conventional type sheets for forming corrugated structures. If desired a plurality of the plaited metal sheets in superposed relation with planar metal sheets brazed or welded therebetween will form a structure of remarkable rigidity and ease of manufacture.

The structure has utility for many purposes, including aircraft structures, wherein great strength properties combined with light weight are essential characteristics.

The invention is also notable for its economy of material and labor, it is readily apparent that a plaited member having planar sides and sharp apexes requires less identical material for a fixed number of flutes per linear foot of a standard height than conventional undulated corrugated medium. The V-flutes, indenters and truss members are preferably formed in one operation, the indenters and apexes being formed as a result of a combination of compression and distension forces.

An object of the invention is to provide a plaited member formed from a sheat of bendable material and comprising integral parallel V-shaped plaits having planar sides alternately folded, the fold lines forming sharp apexes with spaced apart indenters, the indenters having truss members spaced from the apex of the plaits and integral with and connecting the converging sides of a plait immobilizing and rigidifying the plaited structure.

Another object of the invention is to provide a continuous plaited sheet of bendable material of substantial load carrying capacity and resistance to lateral distension comprising parallel counterpart V-shaped flutes with the converging walls of the flutes forming respectively an apex, the apex having indenters at spaced intervals characterized by having spaced apart pairs of side boundaries perpendicular to the line of the apex and an integral truss member intervening the said side boundaries and connecting the respective converging walls of the flute and substantially immobilizing the same.

A further object is to provide a composite board of high load carrying capacity and resistance to lateral deflection comprising a plaited sheet having alternately folded planar walls, the fold lines forming the apex of the flutes and having spaced indenters disposed at substantially right angles to the respective fold line and including a truss connecting the converging planar walls at the bases of the indenters, and a planar facing sheet secured to the apexes on one side of the plaited sheet.

Another object is to provide a composite board structure substantially as described with at least one facing sheet adhesively secured to the plaited sheet with the adhesively positioned on the apex of the plaits and the adjacent portions of the facing sheet and disposed within
the indents providing an adequacy of adhesive bonding surface in conjunction with the sharp apexes and further reinforcing the truss structure.

Still another object is to form a composite structure of high top load carrying capacity comprising a plurality of plaited sheets, with indented apexes and constructed of thin light weight metal, arranged in superposed relation with planar sheets interposed between each pair of plaited sheet components being secured together by brazing or welding.

It is also the object of this invention to provide a plaited corrugated structure as described herein comprised of a succession of transverse parallel plait each that may be formed successively from a continuous web of bendable material in a one step operation by alternately folding the planar walls and indenting or embossing the sharp apexes at substantially right angles to the line of the folds.

These and other objects and advantages of the invention will be apparent to those skilled in the art upon a full understanding of the construction and operation of the plaited structure. The invention also consists in the parts, arrangement and combination of parts hereinafter described and claimed.

The accompanying drawings form a part of this specification and like numerals and symbols therein appearing refer to like parts whenever they occur.

In the drawings:

FIG. 1 is a perspective view of a continuous sheet A in process of forming a plaited, indented sheet.

FIG. 2 is a perspective view of a plaited sheet, showing indents and trusses with a planar sheet B attached.

FIG. 3 is a perspective view partly broken away of a plaited sheet with two planar facing sheets, forming composite paperboard.

FIG. 4 is a section of FIG. 3 taken in the direction of the arrows 4—4.

FIG. 5 is a section similar to FIG. 4 showing adhesive disposed in the indents.

FIG. 6 is a section of a composite board with attached facing sheets taken in the direction of the arrows 6—6 of FIG. 2.

FIG. 7 is a perspective view of another embodiment of the plaited structure wherein the indents are in the form of embossings, integral with the apexes and the respective converging planar walls.

FIG. 8 is a schematic view showing the method of forming a composite fluted structure including the attachment of one facing sheet thereto.

FIG. 9 is a perspective view of a section of one of the paired forming rolls suitable for plaiting and indenting a continuous web in a single operation.

A continuous sheet 22 in the process of being formed into a plaited V-flute structure 21 is shown in FIG. 1 wherein 22 indicates the fold lines at regular transverse intervals and the interposing planar walls 23 of the plait. The fold lines 22 also define the sharp apexes formed by integral pairs of converging planar walls 23 and are disposed in succession on alternate sides of the plaited structure. The fold lines or sharp apexes 22 thus are arranged in parallel planes thereby establishing the surfaces of the plaited structure.

The indents 24 are disposed along the apexes 22 in regularly spaced intervals and are individually arranged in right angular relation to the line of the folds 22.

A more detailed view of the plaited structure is shown in FIG. 2 which also has a facing sheet 25 attached to the apexes 22 on one side of the plaited structure to form a composite structure which when formed of paperboard would be an improvement of the well known single face corrugated paperboard. In this embodiment of the invention it may be seen that the indents 24 are each defined by a pair of parallel free edges 26 and included between said edges are truss members 27. The truss members 27 are spaced from the fold line 22 and are integral with and connect a pair of converging planar walls 23 substantially rigidifying and spacing said walls in predetermined angular relation. The substantially fixed relation of the plaited structure members 27 is effective even in the absence of a facing sheet, as illustrated in FIG. 1 and is effective in minimizing "spring back" as is commonly encountered in forming conventional corrugated board with undulated or sine-like corrugated medium in the well known manner. Thus the plaited structure 21 of and by itself is resistant to longitudinal distention and crushing forces applied perpendicular to the planes of its apexes 22.

FIG. 3 is a perspective view, partly broken away, of a composite board which may be compared to conventional double face paperboard when formed from like materials. The second facing sheet 28 is secured to the alternate fold lines 22 on the opposite side of the plaited structure 21 in respect to the first mentioned facing sheet 25. The thus completed composite structure 29 having two facing sheets 25 and 28 and intervening plaited structure 21 provides a rigid board structure that is not normally subject to significant distortion or folding unless special provision is made as by scoring or other provision of a line of weakness as is well known in the corrugated board art.

The position of the truss 27 is indicated most clearly in sectional view, FIG. 4, taken in the direction of the arrows 4—4 of FIG. 3. It will be noted that the trusses 27 are spaced at an appreciable distance from the apexes 22 of the plait, sufficiently to act as a brace and maintain the determined angular relation of the planar walls 23.

FIG. 5 is a sectional view showing the disposition of the adhesive for securing the plaited structure 21 to the facing sheets 25 and 28. The adhesive material is disposed in the indents 24 above the truss member 27 as well as along the fold line 22, shown in FIG. 2, thus serving to reinforce the truss effect as provided by the invention and in a manner of securing riveting the plaited structure, by means of the adhesive formation in the indents, to the facing sheets 25 and 28. An advantage of the adhesive as well known in the art may be used to secure the components of the composite plaited structure together. It is additionally within the purview of the invention that foamed adhesives may be used to increase the bulk of a given quantity of adhesive material and thereby increase the reinforcing effect. This adhesive forms gaskets between the facing sheets and the sharp apex portions of the plaited structure 21 as well as reinforcing the truss members 27 in the indents 24.

In every case the adhesive, or other means of securing as will be hereinafter described, not only lends to fixably secure the ends or folds 22 of the planar walls but also, in cooperation with the indents 24, serves to, in effect, shorten the column height of the planar walls and results in a more rigid structure than conventional corrugated board wherein the medium is inherently prefixed and therefore more readily subject to increasing deformation by crushing forces. It is thus apparent that the planar walled structure of the invention will have, in comparison to conventional corrugated structures, both a higher initial resistance to deformation by crushing forces and a greater maximum load prior to complete collapse of the structure by excessive crushing forces.

FIG. 6 is a cross sectional view taken in the direction of the arrows 6—6 in FIG. 2 and further illustrates the arrangement and disposition of the component parts of the composite plaited structure.

FIG. 7 illustrates another embodiment of the invention wherein the indents are in the form of embossings 30. The embossings are situated in a like manner to the indents hereinbefore described. However, they are more dependent on the characteristic of the materials and are therefore primarily confined to the practice of the invention with metal sheet materials. The advances hereinbefore described in conjunction with the indented form of the invention will likewise accrue to the embossed form embodiment. The principal difference is that the emboss-
ings are integral throughout their length with the planar walls and the sharp apexes and thereby provide a rigidified reinforced particularly well adapted to plaited metal structures.

The embossed plaited structure, when formed from sheet metals may be secured to one or more facing sheets by known means such as welding or braising. It is further contemplated that a multiple layer structure of superposed embossed plaited structures with intervening planar sheets will provide an advantageous metal sandwich panel comparable in function to conventional honeycomb sandwich panels but affording economies in manufacture and improved structural characteristics. It has been known to use simple V-type metal structures for this purpose, however, these have not proven completely successful due to the extreme directional nature of its strength characteristics. The present invention will also afford an improved bonding to the facing sheets in comparison to conventional honeycomb cores because of the larger brazed joint or bonded area.

FIG. 8 is a schematic diagram showing a method of forming continuous webs of flexible materials into a composite plaited structure in accordance with the invention. The continuous sheet 29 is brought into the machine by pull-in rolls 31 and then fed by guide means 32 and 33 to the one stage forming and perforating rolls 34 and 35. The web 29 is then fluted by the intermeshing arrangement of the rolls 34 and 35, and simultaneously indented or embossed. The fluted web is then retained positioned on the forming teeth of roll 34 by guide shoe 36 until it is transferred to backup roll 37 having a counterpart toothed periphery. Suitable adhesive may then be applied to the sharp apexes of the plaited structure 21 by adhesive applicator roll 38 in a conventional manner as now practiced in respect to single facer sections of conventional paperboard corrugator machines. A facing sheet 25 is then brought into contact with said sharp apexes and adhesively bonded thereto thus providing a composite plaited structure as illustrated in FIG. 2.

A second facing sheet 28 may be secured to the opposite sharp apexes 22 in a similar manner by applying adhesive to the apexes 22 while maintaining the before-mentioned composite structure in a planar relation to form rigid composite panels as illustrated in FIG. 3.

The forming rolls 34 and 35 have complementary spaced tooth arrangements as illustrated in FIG. 9 which is a magnified portion of the periphery of these rolls. The teeth are conventionally formed by laminating circular disc elements 39 and joined tooth elements 40 on a shaft 41. The protruding tooth edges 42 determine the fold lines 22 of the plaited structure in conjunction with the corresponding tooth base 44. The exposed segments 43 of the disc elements determine the disposition of the truss members 27.

The proportion of these forming elements may be varied for particular purposes but it has been found to be generally advantageous to have the protruding tooth elements 40 to have a substantially greater transverse width than the disc elements 39 likewise the angle of the tooth formation is variable but for general purposes an included angle of 90° has been determined to be satisfactory.

The converging faces of the forming teeth should be as nearly planar as the necessary inermination of the teeth will permit in order to obtain the maximum advantage in the resulting plaited structure.

The deflection of the plaited structure planar walls 23 by this necessary deformation has proven to be insignificant as the natural elasticity of the materials used to form plaited board structures is such that they will spring back to the desired planar condition.

It is within the purview of the invention that the teeth may be so formed that the planar walls 23 of the plaited structure 21 may be of dissimilar longitudinal dimension, that is, between adjacent pairs of fold lines.

The amplitude of the forming teeth, that is, the vertical distance between their base and the tooth edges 42 may be varied depending upon the desired use of the resulting construction and the types of materials being utilized. In general, for composite folded paperboard, it will be convenient to provide dimensional relationships comparable to the dimensions of conventional corrugated paperboards. In respect to metals, amplitudes up to several inches may well be provided.

It will be evident, by reference to FIG. 9 that as the one stage forming and perforation rolls 34 and 35 intermesh, providing clearance therebetween for the web 29, the lateral edges of the teeth will provide a shearing action in cooperation with the opposed forming roll disc element exposed portions 43 thus providing the indent free edges 26 of the primary embodiment of the invention.

To provide the second embodiment of the invention as illustrated in FIG. 7, the lateral sides of the teeth elements 40 and exposed portions 43 of the disc elements may be formed with a rounded contour or otherwise spaced apart to avoid the shearing action. In this embodiment of the invention, as well as the first mentioned embodiment, it may be preferable, when plaiting relatively rigid materials such as metals, to provide a straight line operation in advancing the continuous sheet through the forming rolls and maintaining the linear relation until attachment of the facing sheet takes place. By this means distortion of the truss members may be avoided. While the forming rolls may be constructed in various manners, the practice of the invention substantially as described will fall within the scope of the appended claim.

The description of the invention herein provided is considered illustrative only, for the purpose of the disclosure and the invention includes all changes and modifications of the examples, which do not constitute departures from the spirit and scope of the invention.

What we claim is:

A composite board structure comprising at least one planar facing sheet and at least one plaited member, the plaited member having planar wall elements angularly disposed and foldably connected in alternating relation forming apices on the respective sides of the plaited member, each apex having spaced apart indent each defined by a pair of parallel free edges conforming to the contour of the apex and including between said paired free edges truss members integral with the respective converging wall elements and spaced from the fold connections, the truss members disposed in substantially parallel relation to the plane of the apices on each side of the plaited member and reinforcing and connecting the respective adjacent wall elements in determined angular relation, the at least one facing sheet and the plaited member apices on the respective one side in contacting secured relation, adhesive means securing said facing sheet and the plaited member apices, said adhesive means disposed in part in the indents and in part in the angular juncture of the planar elements effectively butressing the apices and rigidifying the board structure.

References Cited in the file of this patent

UNITED STATES PATENTS

1,444,396 Seigle .......................... Feb. 6, 1923
1,987,798 Ruppricht ......................... Jan. 15, 1935
2,042,586 Campbell et al. ................ June 2, 1936
2,107,748 Cohn ............................. Feb. 8, 1938
3,041,223 Sage ........................... June 26, 1962
3,044,921 Wentworth et al. ................. July 17, 1962

FOREIGN PATENTS

300,097 Switzerland ..................... Sept. 16, 1954
427,089 Italy ....................... Nov. 12, 1947