TRIPLE-WALL CORRUGATED BOARD

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

INVENTOR.

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My invention relates generally to corrugated paper board and its component parts, and more particularly to triple-wall corrugated board having a relatively high degree of strength and rigidity.

Corrugated paper board has in recent decades largely superseded wood as a container material, the diversity of shapes, sizes and weights of commodities packaged by corrugated paper board being almost without limit. It is well known that corrugated board is a structural material characterized by economy, high strength for a given weight and good cushioning and insulating values. But when more than one layer is available a multiplicity of materials, the factors which make for strength and rigidity when these materials are combined into a corrugated board have not been fully appreciated or exploited.

Corrugated board of conventional design may be of the single face, double face or double wall type. Single face refers to a combination of one liner bonded to a sheet of corrugating media or fluting, the liner preventing the arches from flattening out. In double face, the fluting is sandwiched between two liners, while in the double wall type, three liners are provided which are separated by two sheets of fluting material. Double face and double wall boards are used in the manufacture of containers, whereas the use of single face is confined to wrapping and cushioning.

Double face and double wall containers are distinctly limited in structural strength. Because of its superior structural and cushioning properties, increased use has been made of three-ply corrugated board for the purpose of packaging relatively heavy objects or for protecting frail objects in transit. These containers are preferably constructed of corrugated board manufactured in accordance with U.S. Patent No. 2,739,532, issued August 21, 1956, to Goldstein et al. and identified by the trademark "Tri-Wall Pak." Containers of "Tri-Wall Pak" board have in many instances replaced boxes made of plywood, lumber and other packaging material. Tests have shown that even if a loaded box of triple-wall corrugated construction is dropped, it does not shatter like wood but continues to give full protection to its contents.

There are many variables involved in the construction of corrugated board. For example, three types of corrugations are presently in use; namely, types A, B and C. At least seven corrugating mediums are available in a wide range of weights in conjunction with three types of liner sheets in a yet wider range of weights. The sheets may be fabricated either with a starch or silicate adhesive or in some cases with both. However, for purposes of the present discussion, it will be assumed that the sheets are properly bonded together simultaneously in the manner set forth in the above-identified patent and that the variables which determine the ultimate board strength are those arising from the types and weights of fluting and liner sheets. Should all of the sections of triple-wall board be bonded together by hand or non-simultaneously by other techniques, then other variables are introduced which make it difficult if not impossible to predict or control the ultimate strength of the board.

Corrugated board is subjected to certain tests in evaluating its structural and performance properties. The compression test is possibly the most commonly used in analyzing the relative efficiency of corrugated fiber board containers. By top-to-bottom compression testing one may compare the ability of different boards to sustain stacking loads.

When a commodity which is packaged cannot itself sustain crushing loads, the compression test is of value in indicating the protection afforded to the contents as well as the stacking characteristics since the resistance to compression falls largely on the walls of the box. With the growing use of triple-wall board in the packaging of very heavy objects, the need for enhanced compression characteristics is of increasing importance.

Accordingly it is the primary object of my invention to provide a triple-wall corrugated paper board having improved top-to-bottom compression characteristics, thereby to enhance the column test and stacking properties of containers formed thereby.

More specifically it is an object of my invention to provide a triple-wall corrugated board in which the flute sizes and liner weights of the components are so chosen and arranged relative to each other as to provide optimum strength and rigidity.

Briefly stated, in a triple-wall corrugated board in accordance with the invention, three fluting sheets are combined adhesively with four liners, two of which are of relatively light weight and being placed immediately in the board, the two heavier liners being placed on the outside. The fluting sheets are of such types and in relative positions as to dispose the inner and outer liners the greatest distance from the neutral axis of the board to provide the highest possible moment of inertia.

For a better understanding of the invention as well as other objects and further features thereof, reference is had to the following detailed description to be read in connection with the accompanying drawing, wherein:

Fig. 1 is a cross-section of double face corrugated board having an A-flute.
Fig. 2 is a cross-section of double face corrugated board having a B-flute.
Fig. 3 is a cross-section of double face corrugated board having a C-flute.
Fig. 4 is a cross-section of triple-wall corrugated board in which the combined fluting arrangement is A—A—A.
Fig. 5 is a cross-section of triple-wall corrugated board in which the combined fluting arrangement is C—A—A.

As pointed out in the foregoing general discussion, the physical properties of the corrugated medium contribute materially to the characteristics of the finished board and the products manufactured therefrom. Among the types of coarse paper board most generally used as corrugating media are strawboard, bogus, semi-chemical, Fourdrinier Kraft, cylinder Kraft, etc., each of which has properties of value for specific applications. The flutes of the corrugated walls are specified by size A, B or C.

As shown in Figs. 1, 2 and 3, "A" flute is approximately 1/8 of an inch high with 36 flutes or corrugations per linear foot. "B" flute is approximately 1/6 of an inch high with 50 corrugations per foot, whereas "C" flute is about 1/2 of an inch high with 42 corrugations per foot. Thus the dimensions of "C" fall between "A" and "B."

It is known that a close correlation exists between flute size and cushioning ability as well as crushing and compressive forces. Other things being equal, "A" flute will produce board with the least flat crush-resistance and "B" flute the most. This property is of importance where cushioning or shock absorption is required. But in top-
to-bottom compression tests, boxes made of "A" flute board will give the highest results, "B" flute the lowest results, with "C" flute naturally falling midway between the results obtained from "A" and "B". But the properties which result from combining flutes into a triple-wall board has not heretofore been understood or exploited.

I have discovered that the relative disposition of the flutes and the liners in triple-wall board is highly significant in determining its ultimate physical characteristics. For example, the normal assumption is that a triple-wall board composed of A—A—C would not differ materially from a conventional board of the same thickness composed of A—C—A. Yet I have found there are highly important differences which depend not only on the types of fluting which are combined but also on relative disposition of heavy and light liners. The theoretical basis for this discovery will now be treated in some detail.

A well-established principle of mechanical engineering is that the greatest strength and rigidity in a structural member having a given amount of material is realized by disposing the surfaces subjected to stress so that they are as far apart as possible to provide the greatest moment of inertia. Thus a steel I-beam in which two parallel flanges are held at a distance from each other by a thin connecting web is considerably stronger and stiffer than a square rod of the same cross-sectional area.

It is therefore possible to consider a single wall of corrugated board as analogous to an I-beam, with the outer liners corresponding to the flanges and the fluting acting as the connecting web. From this it will be appreciated that the greatest strength and rigidity will result by using the highest conventional flute to attain the greatest separation, thereby disposing the maximum amount of material the greatest distance from the neutral axis.

The neutral axis in a beam subjected to a bending action is that line or plane in which the fibers are neither stretched nor compressed or where longitudinal stress is zero. A wall of corrugated board may, as pointed out above, be treated as a beam and the neutral axis of a single board will normally run longitudinally through the center thereof. The position of the neutral axis of a corrugated board, such as triple-wall corrugated, is normally also through the center when the construction is symmetrical as with an A—C—A combination or a C—C—C combination, but when the arrangement is unsymmetrical, the axis line is more difficult to establish mathematically.

The moment of inertia of a solid body with reference to a given axis is the limit of the sum of the products of the masses of each of the elementary particles in which the body may be conceived to be divided and the square of their distance from the given axis. Thus if in the triple-wall board liners are placed as far as possible from the neutral axis, with the heaviest liners on the outside, the greatest possible moment of inertia will be attained.

The relation between moment of inertia and the components of triple-wall corrugated board can be demonstrated by comparing the moment of inertia calculations for several boards made from various combinations of A, B and C corrugated sections and employing two light and two heavy liners in the construction.

Referring first to Fig. 4, there is shown a triple-wall board having three A flutes in combination with four fluting sheets. Two liners are outside and two are intermediate the corrugations. In Fig. 5, the combined fluting arrangement is C—A—A.

For the thickness values needed in making the calculations, the light liners used for this comparison were assumed to be .016 inch thick (about 42 pounds per thousand square feet) and the heavy liners were assumed to have a .030 inch thickness (about 90 pounds per thousand square feet). The calculations are recorded in the table below:

| A—A—A (Fig. 4) | .09919 | .09045 |
| A—C—A | .05531 | .05470 |
| C—C—C | .05193 | .05210 |
| C—B—A | .049175 | .052074 |
| C—A—A (Fig. 6) | .05527 | .054591 |

In the above table the second to the fifth examples are included to show by their contrast the jump in the moment of inertia obtained by the present invention. With the heavier liners on the outside both the A—A—A and C—A—A boards have a moment of inertia exceeding .006000 to a substantial degree. All other combinations in the table are substantially less. Correspondingly, even when the lighter liners are on the outside and the heavier liners are on the inside, again the A—A—A and C—A—A combinations show that the greater moment of inertia result, as compared to the second to fifth examples.

It will be seen that the greatest moment of inertia is obtained for the combination A—A—A board of Fig. 4 when the heavy liners are placed on the outside. Assuming that the neutral axis runs through the center of the board, it will be evident on inspection that the greatest weight of the board is displaced the maximum distance from this axis, the lighter liners being closest to the axis. On the other hand, in the reverse situation with the heavier liners on the inside, the resultant moment is substantially less in value.

The next highest moment of inertia is obtained for the C—A—A board in Fig. 5 with the heaviest liners on the outside. The moment of inertia in this case also reduced when the locations of the liners are reversed, but is greater by comparison with the second to fifth examples in the last column of the table having corresponding liner arrangements.

It will be evident from the foregoing that superior strength and rigidity are obtained in triple-wall corrugated by so arranging the fluting types and the liners with respect to their weights as to obtain maximum spacing between the outer liners and by disposing a maximum amount of material the greatest distance from the neutral axis. Specifically, this is accomplished by always placing the heavier liners on the outside lighter liners being disposed in intermediate position, and by a relative orientation of fluting so that the inner liners are as far as possible from the neutral axis.

A better understanding of the effect of the moment of inertia on the structural characteristics of the board may be gained by analyzing the inertia values in the light of their influence on the maximum load attained in a column test. Assume that the Euler column strength formula is applicable for a certain set of conditions in which the load is:

\[ P = \frac{4EI}{l^2} \]

where

- \( E \) is a factor for fixed ends
- \( I = \text{modulus of elasticity for material of the column} \)
- \( l = \text{length of column in inches} \)
- \( I = \text{moment of inertia} \)

It may be seen that with two columns of triple-wall corrugated constituted by like components, employing the same three kinds of flutes, and differing only...
from the flute and liner arrangement, the buckling load will vary directly as the moment of inertia values varies. Thus, if in one instance the moment of inertia is twice that of the other, the load would be twice that of the column having the smaller amount of inertia.

The moment of inertia (I) together with the modulus of elasticity (E) are ordinarily designated as the stiffness factor (EI) in beam bending and column formulas.

In actual tests it was found that the theoretical reasons stated above for combining fluting type and liner weights as they relate to moment of inertia were fully substantiated. Column tests were conducted on the board combinations referred to above and the highest column load was obtained for the board having the greatest moment of inertia, namely, a board consisting of three A flute sections and having 90-pound liners on the outside and 42-pound liners placed in intermediate positions. The moment of inertia of this board was 1.54 times as great and the actual column load 1.72 times as great as against board having one outer C section with an A flute center and inner sections and having the two 42-pound liners on the outside with the 90-pound liners on the inside.

The influence of liner arrangement on the moment of inertia, and in turn on actual column test load can be demonstrated by comparing a board composed of three A flute sections having the heavier liners on the outside with another board also composed of three A flute sections but with the lighter liners on the outside. In this case the moment of inertia was found to be about 1.4 times as great in the case of the A-A—A board with the heavy liners on the outside and the actual column test load was about 1.5 times as great as it was for the A—A—A board with the heavy liners on the inside.

Preferred embodiments of triple-wall corrugated paperboard in accordance with the invention may be specified as follows: All corrugated sections are of at least 26-pound base weight paperboard of kraft, chestnut, bogus, strawboard or semichemical corrugating media. The outer liners are of 90-pound base weight kraft paperboard or material of equivalent strength. The built-up board is of triple-wall construction such that one outer corrugated section is of A- or C-flute type, the intermediate section is of A-flute, the other outer section being also of A-flute such that the resulting thickness of the board is not less than $\frac{3}{4}$ inch. In brief, the board is either of A—A—A or A—A—C, and in either case, the two lighter liners are placed on the inside and two heavy liners on the outside to provide the optimum moment of inertia. It is also to be noted that corrugated board manufactured in accordance with the invention is also considerably improved in its puncture-resistance characteristics.

While there has been shown what are considered to be preferred embodiments of the invention, it will be manifest that many changes and modifications may be made therein without departing from the essential spirit of the invention. Thus while the specification speaks of A, B and C types of fluting, other types which may hereafter be developed may be combined in accordance with the principles underlying the invention. It is intended, therefore, in the annexed claim to cover all such changes and modifications as fall within the true scope of the invention.

What is claimed is:

Triple-wall corrugated paperboard consisting of three fluted paper sheets and four flat paper liner sheets combined and bonded together simultaneously with two of the liner sheets located on the outside of the paperboard and being about .030 of an inch thick and weighing about 90 pounds per 1000 square feet and with the other two of the liner sheets located at intermediate locations in the paperboard and being about .016 of an inch thick and weighing about 42 pounds per 1000 square feet, one of the fluted sheets being located between the intermediate liner sheets and having flutes which are A size, the other two fluted sheets being respectively located between the intermediate and outside liner sheets in each instance, one of these other two fluted sheets having flutes which are A size and the other of these other two fluted sheets having flutes which are C size, said A size flutes being approximately $\frac{3}{4}$ of an inch high with approximately 36 flutes per linear foot and said C size flutes being approximately $\frac{3}{4}$ of an inch high with approximately 42 flutes per linear foot.

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UNited States patent Office
Certificate of correction

Patent No. 2,985,553
May 23, 1961

Herbert R. Anderson

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below:

Column 4, Table 1, under the heading "Moment of Inertia, inches to 4th power per inch", column 2, line 2 thereof, for "0.004351" read -- 0.004251 --.

Signed and sealed this 21st day of November 1961.

(Seal)
Attest:

Ernest W. Swider
Attesting Officer

David L. Ladd
Commissioner of Patents
USCOMM-DC