July 8, 1958 H. W. A. PAULSSEN 2,842,237

METHOD AND MEANS OF IMPROVING THE STRUCTURAL CHARACTERISTICS OF SHEET MATERIAL

Filed June 6, 1955 4 Sheets-Sheet 1

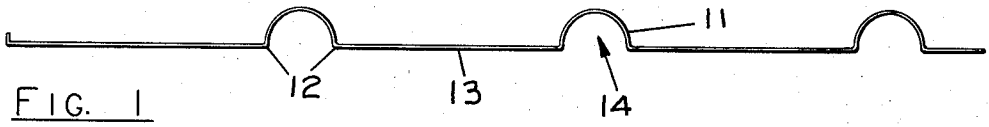


FIG. 1

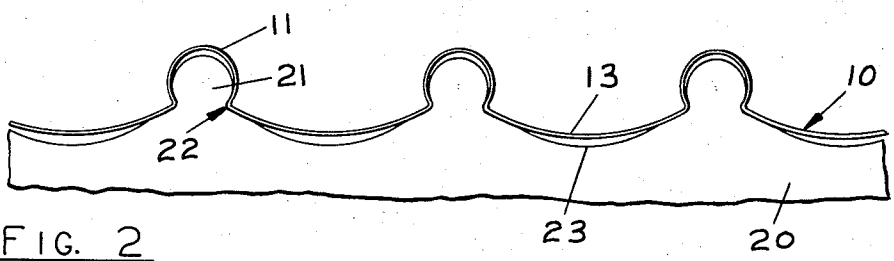


FIG. 2

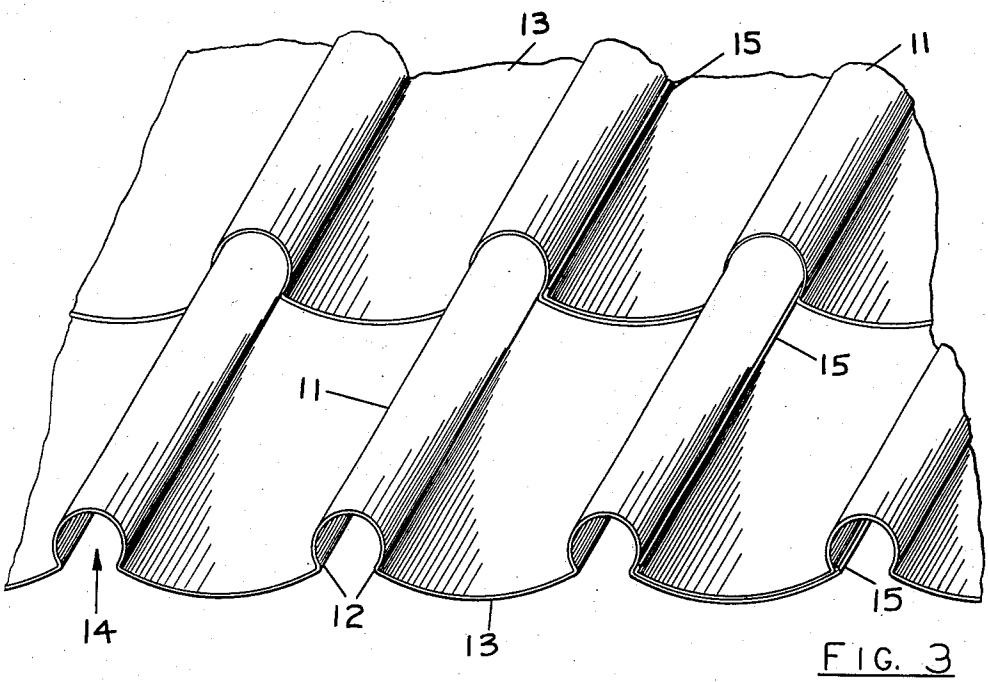


FIG. 3

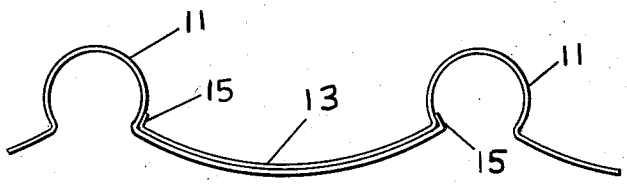


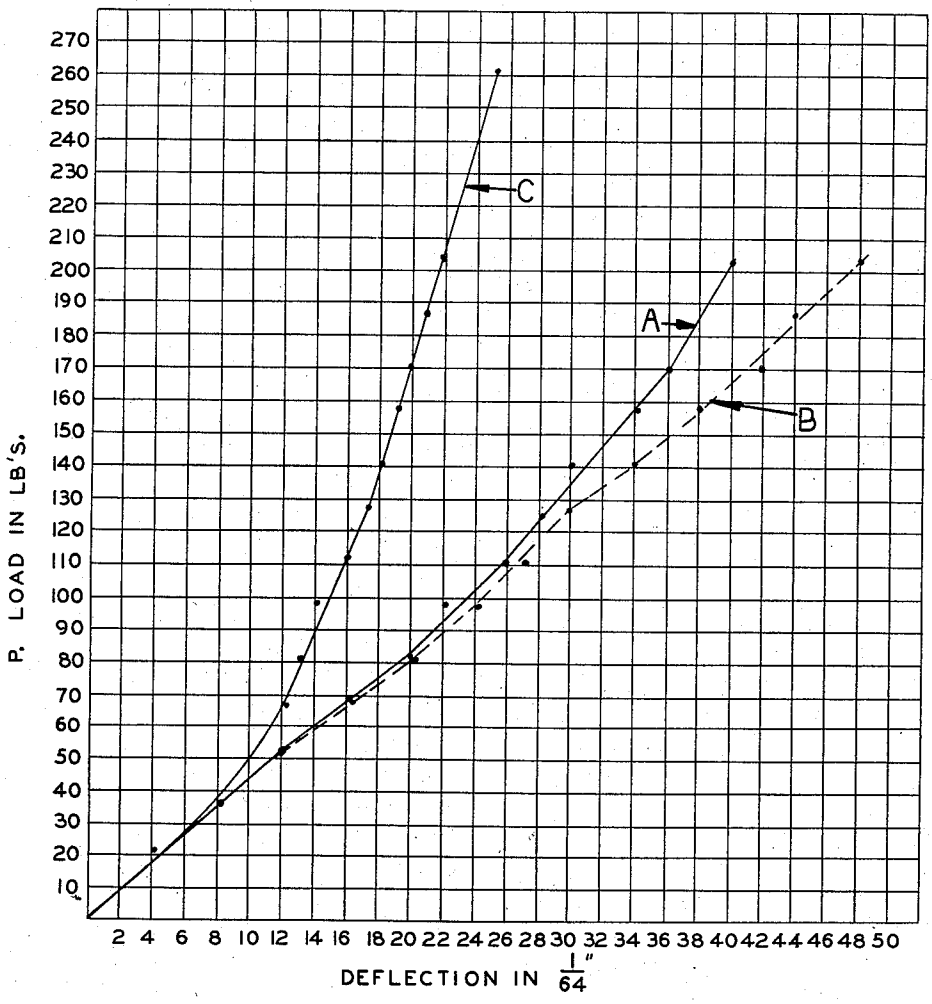
FIG. 4

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A- CORRUGATED SHEET - WEBS STRAIGHT - NOT PRESTRESSED

B- CORRUGATED SHEET - WEBS DOWNWARDLY CURVED BUT NOT PRESTRESSED

C- PRESTRESSED CORRUGATED SHEET

FIG. 5

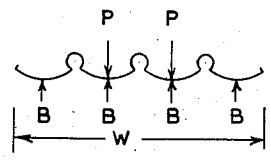


FIG. 6

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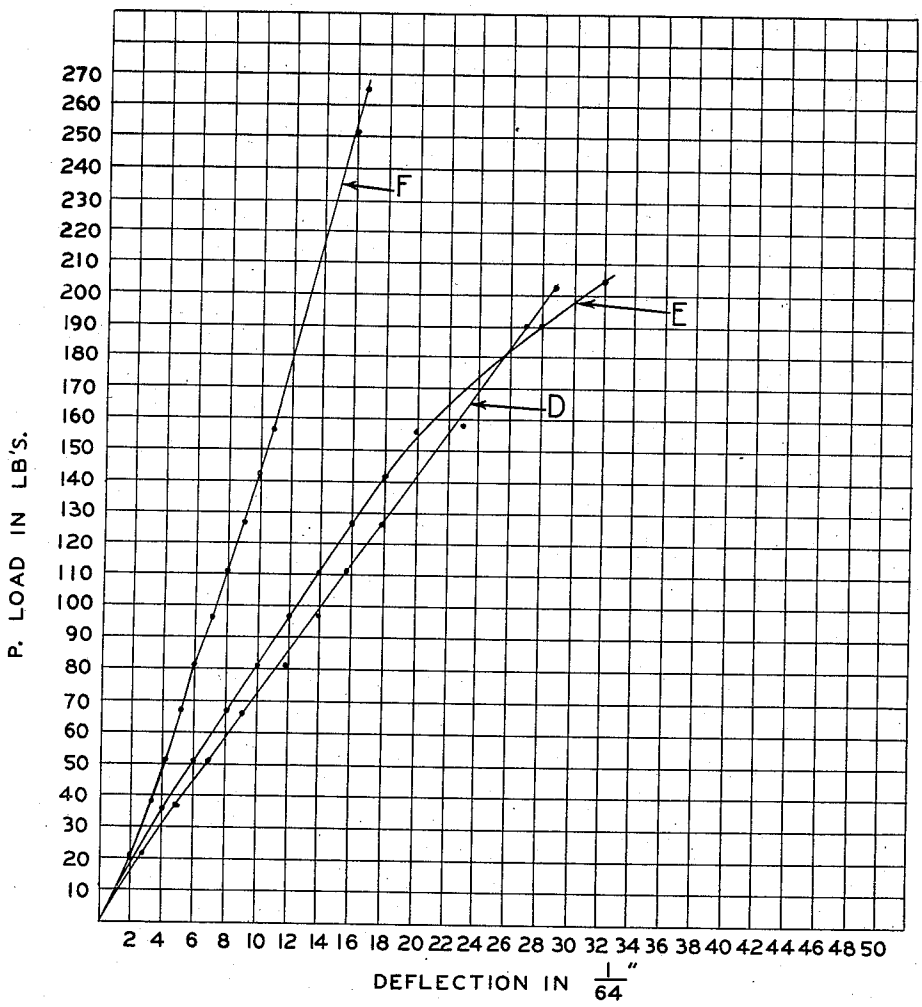
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METHOD AND MEANS OF IMPROVING THE STRUCTURAL CHARACTERISTICS OF SHEET MATERIAL

Filed June 6, 1955 4 Sheets-Sheet 3



D- CORRUGATED SHEET - WEBS STRAIGHT - NOT PRESTRESSED

E- CORRUGATED SHEET - WEBS DOWNWARDLY CURVED BUT NOT PRESTRESSED

F- PRESTRESSED CORRUGATED SHEET

FIG. 7

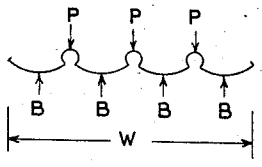


FIG. 8

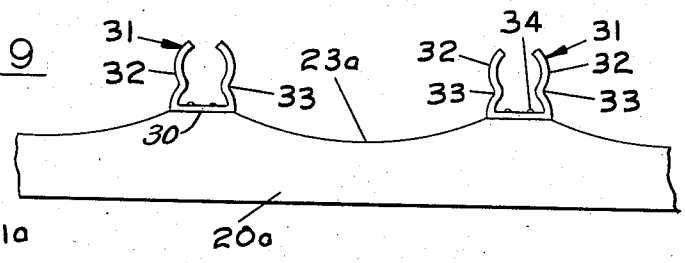
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METHOD AND MEANS OF IMPROVING THE STRUCTURAL CHARACTERISTICS OF SHEET MATERIAL

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FIG. 9



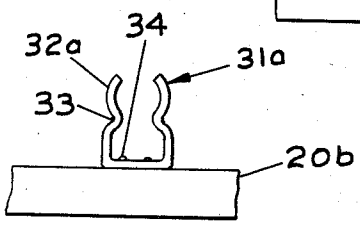


FIG. 10

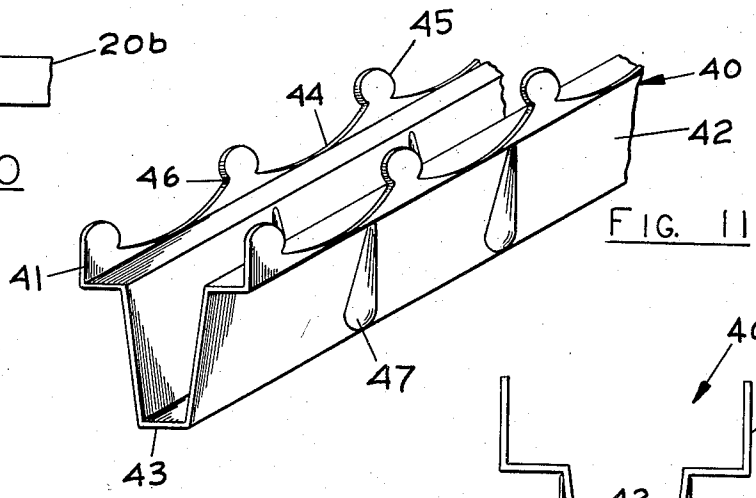


FIG. 11

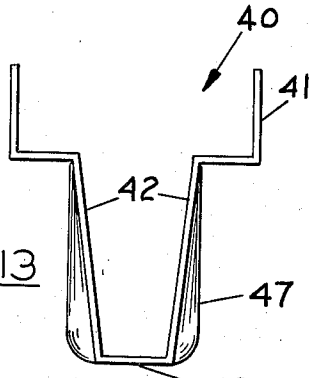


FIG. 13

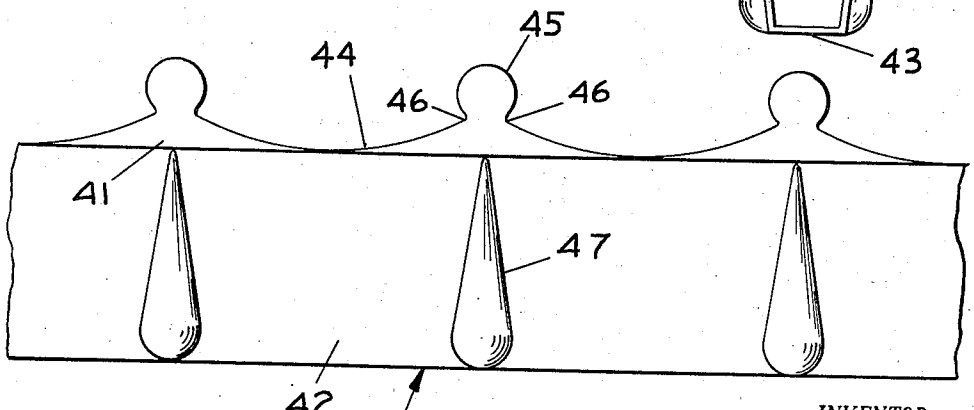


FIG. 12

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2,842,237

METHOD AND MEANS OF IMPROVING THE STRUCTURAL CHARACTERISTICS OF SHEET MATERIAL

Horst W. A. Paulssen, Muskegon Heights, Mich.

Application June 6, 1955, Serial No. 513,343

4 Claims. (Cl. 189—85)

This invention relates to sheet material and more particularly to a sheet material which is corrugated and, at the time of installation, the webs between the corrugations are compressed by giving them a concave deflection within the elastic limit of the material. The compression of the sheet generates forces within the sheet which increases the material's resistance to deflection under applied loads.

It is a well known and frequently used expedient to stiffen a sheet of thin material by corrugating it in order to increase its moment of inertia. Thus, its resistance to bending under an applied load is increased. These corrugations take many forms from simple U-shaped ridges to more complex shapes including reinforced ridges having a generally wedge-shaped cross section. While corrugation alone does effect a substantial increase in the sheet's capacity to resist deflection under applied loads, this invention is designed to increase still further the resistance of such materials to deflection while using the simplest form of corrugation.

By compressing the webs between each of the ridges or corrugations which in turn puts the ridges or corrugations under tension, the resistance of the sheet to deflection under applied loads is substantially increased, irrespective of whether the loads are applied to the ridge crowns or to the intermediate webs or both. This increase in resistance to deflection permits the use of either substantially thinner gauge material for a given set of operating conditions or the use of a material of identical gauge but with a substantial increase in the spacing between supports axially of the ridges.

These objectives have been obtained without increasing the complexity of the fabrication problem involved in the material's manufacture. This invention utilizes a sheet having corrugations which in their preferred form are a segment of a true circle. Therefore, the open faces of the corrugations are at least as wide as the maximum internal width of the corrugations before installation. Thus, the necessity for difficult, reverse forming of the sheet on the sides of the corrugations is eliminated. The invention permits the fabricated material to be shipped in compact stacks. This substantially decreases the cost of transportation. Sheets fabricated pursuant to the teachings of this invention are adapted to high speed, continuous manufacture. This also substantially reduces the initial cost of the product.

The advantage of a substantial increase in the finished material's resistance to deflection is obtained without the necessity for increasing the height of the ridges. Thus, the total quantity of material required to form a sheet practicing this invention is almost the same as that required in practicing the more conventional non-prestressed constructions. The only loss in area of the sheet over that of more conventional corrugated material is approximately the five percent shrinkage resulting from the arching of the webs between the corrugations and the contraction of the corrugations to effect the prestressing. This, however, is counterbalanced by approximately a one hundred percent increase in the resistance of the material to deflection.

The invention adapts the material to simplified installation methods. It is merely seated over suitable supporting ridges at widely spaced intervals. The webs between the ridges are, one by one, arched and the ridges in progressive order made to seat about and engage the supporting structure. The arching of the webs urges the apices at the juncture of the ridges and the webs to pinch inwardly and thus firmly grip the supporting structure about which the ridges are seated. Thereafter, the remaining compression in the webs and tension in the ridges act as a positive force, urging the sheets into firm, gripping relationship with the supporting structure.

The application of the teachings of this invention provides a covering material which is rigid in all directions. In circumstances involving vibration, it eliminates drumming of the webs since they are compressed and slightly arched. This eliminates any possible oil canning effect. For any given particular load, it permits a much thinner gauge material to be used, thus reducing both the cost and the weight of the installation.

These and other objects and purposes of this invention will be immediately understood by those acquainted with the forming of structural members upon reading the following specification and the accompanying drawings.

In the drawings:

Fig. 1 is a fragmentary, end elevation view of sheet employing this invention, after fabrication but before installation.

Fig. 2 is a fragmentary, end elevation view of the sheet shown in Fig. 1, after installation.

Fig. 3 is a fragmentary, oblique view of a plurality of sheets employing this invention installed with their margins in overlapping relationship.

Fig. 4 is an enlarged, fragmentary, end elevation view of the joinder of the ends of two sheets employing this invention.

Fig. 5 is a comparative chart of test results of prestressed and non-prestressed material.

Fig. 6 is a diagrammatic sketch of the conditions under which the tests were made, the results of which are graphically presented in Fig. 5.

Fig. 7 is another comparative chart of tests made on prestressed and non-prestressed material.

Fig. 8 is a diagrammatic presentation of the conditions under which the tests were made, the results of which are graphically presented in Fig. 7.

Fig. 9 is a fragmentary, side elevation view of a support equipped with a mounting clip for my invention.

Fig. 10 is a fragmentary, side elevation view of a support equipped with a modified mounting clip.

Fig. 11 is a fragmentary, oblique view of a beam specifically designed to mount this invention.

Fig. 12 is a fragmentary side elevation view of the beam illustrated in Fig. 11.

Fig. 13 is an end elevation view of the beam illustrated in Figs. 11 and 12.

Referring specifically to the drawings, the numeral **10** indicates a sheet of comparatively thin gauge metal such as is used for metal siding or roofing. While this invention may be employed with materials having a wide range of thickness, for purposes of illustration and without any intent to limit the scope of this invention, it will be assumed that the sheet is of 22 gauge aluminum. It will also be recognized that the material may be selected from a wide variety of materials, such as aluminum, copper, steel, bronze, or plastic.

The sheet **10**, at the time of corrugation, may have been severed into individual sheets or it may be fabri-

cated continuously from coil or strip stock. This sheet is passed through a machine equipped with dies suitable for forming the ridges **11**. The ridges **11** project outwardly from the sheet. All the ridges **11** project in the same direction with relation to the center plane of the sheet **10**. The ridges **11**, as formed in the material, have the general shape of an inverted U and are preferably a true segment of a circle and at their open ends the sides of the ridges form comparatively sharp apices **12** with the edge margins of the webs **13**. These apices **12** preferably are formed by bending the sheet over a radius which normally closely approaches the minimum radius permissible for the particular type and gauge of material being employed. It will be noted that the throat or open bottom of the ridges **11** is not in any way constricted, this throat being at least as wide as the maximum internal cross section of the ridge **11**.

The ridges **11** are uniformly spaced across the sheet and are separated by webs **13**. As the sheet is initially formed, the webs **13** are straight and, thus, each of them, when the sheet is laid out flat, lie in the same plane. At the edge margins of the sheet, an upturned marginal flange **15** is formed (Fig. 4). The flange **15** provides an abutment means for retaining the web in its prestressed condition when the sheet is mounted. The specific use of this marginal flange will be described more fully hereinafter.

When the sheet **10** is mounted, it is supported by beams **20** (Fig. 2). These beams extend transversely of the ridges **11** and are spaced apart axially of the ridges **11** at suitable spacings to support the sheet. These spacings will depend upon the expected applied load and the gauge of the material from which the sheet is fabricated. At intervals conforming to the spacing of the ridges, when the sheet is in its installed position, the beam **20** is provided with upwardly extending projections or bosses **21**, designed to seat within the ridges **11**.

The bosses **21** are so shaped that when the sheet **10** is installed the crown of the bosses and the crown of the ridges are spaced apart vertically. Where the bosses **21** merge into the beam **20** proper, the side walls of the bosses are undercut slightly to form shallow, lateral channels **22** (Fig. 2). In the particular arrangement of the beam illustrated in Fig. 2, the portions extending between the bosses **21** are concavely formed to prevent contact between the web **13** and the beam **20** at least at the center of the concavity after installation.

When the sheet **10** is installed, the ridges **11** are moved slightly toward each other, thus compressing the webs **13** and arching them downwardly. This imparts to the webs **13** uniform, slight concavity. This places the webs **13** under compression and the crowns of the ridges **11** under tension. At the same time, the apices **12** at the throat of each of the ridges are forced toward each other, constricting the neck opening **14** of each ridge. This forces the apices **12** into the channels **22** on each side of the bosses **21**. The webs **13**, being under compression, urge the apices **12** to converge and thus to grip tightly the bases of the bosses **21**. Thus, the sheet is firmly and securely attached to the beam **20** without the use of conventional fasteners. Further, because of the concavity of the webs **13**, any attempt to vertically lift the sheet **10** from the bosses **21** will result in further tightening the grip of the apices about the bosses **21**.

This concaving of the webs **13** to place them under compression prestresses the sheet. Not only does it prestress the webs **13** but also, in placing the crowns of the ridges **11** under tension, it slightly lowers them in order to provide a portion of the material necessary to permit the apices to pinch inwardly about the bosses. So long as the material remains in this locked position, the webs remain under compression and the crowns of the ridges remain under tension. It will be noted that the concave, upper surface **23** of the beam **20** does not touch the webs **13**, at least at the center of the concavities. Thus, all of

the support for the sheet **10** is provided at or adjacent the margins of the webs. As the ridges are constricted and placed under tension in the installation of the sheet, they are caused to assume a segment of a true circle of greater arc length but of reduced radius.

The necessity for providing spacing between the centers of the webs **13** and the concavities **23** of the beam when installed arises from the fact that the webs must be temporarily deflected to a greater degree in order to permit installation of the apices **12** about the bosses **21**. In so mounting the sheet **10**, its overall width is reduced by approximately five percent because that much material is absorbed in forming the concavity of the webs **13**. This has to be so since the webs are not naturally downwardly arched but are placed under a positive, compressive load by pushing the ridges together so that each web, after installation, actually spans a lesser distance than the width of that web when it was in its relaxed or normal condition.

The important feature of the prestressing of these sheets is the placing of the webs under compression by giving them a concave shape and as a consequence placing the crowns of the ridges in tension. This results in an increase in the rigidity of the sheet. To determine this, comparative tests were conducted on material of identical cross sectional configuration and gauge to ascertain the deflection under applied loadings. These tests are set forth in the following examples.

EXAMPLE I

A sheet of 22 gauge aluminum was corrugated and formed with three ridges spaced 11.3125 inches apart, center to center and having a height of 1.250 inches. The sheet, after corrugation, had a width W of 40.8125 inches and was mounted on a beam similar to the beam **20** (Fig. 2). In the mounting of the sheet to conduct the test involving a prestressed condition (Test C), the webs between the ridges were deflected concavely to place them under compression. This deflection of the webs resulted in a decrease in the overall width of the sheet from 40.8125 inches to 38.25 inches, thereby decreasing the covering area of the sheet approximately 5.4 percent. It was supported by beams spaced four feet six inches apart and the load was applied to the webs between the ridges or corrugations at the center of the span, midway between the beams. Since three ridges were formed in this sheet, the load was applied equally to the two webs between the three ridges. Three tests were made with this sheet.

In Test A, the sheet was placed on a straight beam without the bosses **21**. The webs were supported by direct contact with the beams, indicated by the arrows B (Fig. 6). The webs, at the beginning of the test were straight, having no concavity. The load was applied gradually and the deflection measured after application of each increment of load. The test showed that when a load P of approximately 109 lbs. was applied, the sheet deflected approximately $^{25}/_{64}$ and when a load of approximately 203 lbs. was applied, the sheet deflected approximately $^{40}/_{64}$. The results of this test are graphically presented as line A in Fig. 5.

In Test B, the same corrugated sheet was employed but with the webs arched downwardly and not placed under compression. A beam was provided having concave portions to securely support each of the webs across its entire width. The concavity of the webs was the same as that resulting from prestressing, the only exception being that the concavity was placed in the sheets by pre-forming and the sheets were under no load or prestress when the test started. The loading conditions were the same as those employed for Test A. The results of this test show that when a load of approximately 105 lbs. was applied, the sheet deflected $^{25}/_{64}$ and when a load of approximately 204 lbs. was applied, the sheet

deflected approximately 4⅜₆₄. The results of this test are graphically presented as line B in Fig. 5.

Test C was conducted with an identical sheet except that a beam **20** was employed and the sheet was pre-stressed as described above in this example. The sheet was supported only at or adjacent the margins of the webs, clearance being maintained between the centers of the webs and the supporting beam. The loading conditions were identical to those used in Tests A and B. This test showed that when a load of approximately 105 lbs. was applied, the sheet deflected approximately 1⅝₆₄ and when a load of approximately 261 lbs. was applied, the sheet deflected approximately 2⅝₆₄.

The test indicated that while pretressing resulted in an area loss of approximately 5.4 percent of the total covering area, it resulted in a gain in the resistance of the sheet to deflection of approximately 103 percent. Thus, the loss in area was slight by comparison with the gain in resistance to deflection under applied loads.

EXAMPLE II

In the second series of tests, the conditions were identical to those in the first series of tests described in Example I. The only difference was the fact that the loads were applied to the crowns of the ridges rather than to the webs. The load was applied at the midpoint of the span with the load evenly divided between each of the three ridges as indicated by the arrows P in Fig. 8.

In Test D the sheet was placed on a straight beam without the bosses **21**. The webs were supported by direct contact with the beam indicated by the arrows B. The webs, at the beginning of the test, were straight, having no concavity. The load was applied gradually and the deflection measured after application of each increment of load. The test showed that when a load P (Fig. 8) of approximately 66 lbs. was applied, the sheet deflected approximately ⅜₆₄ and when a load of approximately 203 lbs. was applied, the sheet deflected approximately 2⅜₆₄. The results of this test are graphically presented as line D in Fig. 7.

In Test E the same corrugated sheet was employed but with the webs arched downwardly and not placed under compression. A beam was provided having concave portions to securely support each of the webs across its entire width. The concavity of the webs was the same as that resulting from prestressing, the only exception being that the concavity was placed in the sheets by pre-forming and the sheets were under no load or pre-stress when the test started. The loading conditions were the same as those employed for Test D. The results of this test show that when a load of approximately 66 lbs. was applied, the sheet deflected approximately ⅜₆₄ and when a load of approximately 203 lbs. was applied, the sheet deflected approximately 2⅜₆₄. The results of this test are graphically presented as line E in Fig. 7.

Test F was conducted with an identical sheet except that a beam **20** was employed and the sheet was pre-stressed as described in the forepart of Example I. The sheet was supported only at or adjacent the margins of th webs, clearance being maintained between the centers of the webs and the supporting beam. The loading conditions were identical to those used in Tests D and E. This test showed that when a load of approximately 66 lbs. was applied, the sheet deflected approximately 5⅜₆₄ and when a load of approximately 203 lbs. was applied, the sheet deflected approximately 13⅜₆₄. When a load of 265 lbs. was applied the deflection was approximately 17⅜₆₄. The results of this test are graphically presented as line F in Fig. 7.

Modifications

Fig. 9 illustrates a modified form of a beam and mounting bracket usable for anchoring and supporting this panel. The beam **20***a* has its upper surface formed into a series of spaced, shallow, concavities **23***a*. Between each of the concavities is a raised, flat boss **30**. The top surface of the bosses **30** are flat and mount an attachment bracket **31**. The attachment bracket is somewhat U-shaped, having sides **32**, each provided adjacent its base with a shallow pocket **33**. The shallow pocket **33** corresponds to the shallow channel **22** of the bosses **21** on the beam **20**. The brackets **31** are attached to the beam by fasteners **34** passing through the web of the bracket into the beam **20***a*.

The bracket **31** is preferably formed of a strip material approximately an inch or two in width. It is of relatively heavy gauge to prevent deflection of the sides under the urging of the compressed webs **13** of the sheet. These brackets provide an inexpensive and easily installed means of securing the sheet **10** to its supporting structure. Since the sheet needs support only at the ridges and at periodic spacings axially of the ridges, it is entirely feasible to use this type of mounting bracket.

The mounting bracket **31***a* illustrated in Fig. 10 is designed for use on a supporting beam **20***b* and eliminates the necessity of forming concavities in the top surface of the beam. To do this, the sides **32***a* of the bracket **31***a* are longer, permitting the pocket **33** to be raised substantially above the top surface of the beam. Thus, the concave webs of the sheet **10** will be supported above the beam's surface. Other than the greater length of the sides **32***a*, the mounting bracket is identical to that illustrated in Fig. 9 and may be made of the same material and installed in the same manner.

Figs. 11 and 12 illustrate a beam, preferably of rolled shape, particularly adapted to the mounting of this type of sheeting. The beam **40** is basically a U-shaped channel having its upper portion **41** wider than its lower portion **42**. The channel is closed at the bottom by the web **43**. The top of the sides of the upper portion **41** are cut to provide the concave sections **44** and the bosses **45** with the notches **46** at the juncture of the base of the bosses with the concave portions **44**. Both sides of the wide portion **41** are so formed. Thus, the sheets **10**, when mounted, will be supported in two places at each beam axially of a ridge or corrugation. This beam provides both a mounting means for the sheet and a structural support for the whole roof, capable of carrying both the weight of the sheets **10** and the operating load applied to the structure.

The beam **40** may be best formed by passing it through suitable dies to form the concavities **44** and bosses **45** in the edges of a strip of suitable material such as steel or aluminum. The formed sheet is then passed through suitable rolling dies to roll the sides up into the desired sectional shape. It will be recognized that although one particular shape is illustrated, that, for structural purposes, a number of different shapes may be employed and the particular cross sectional shape of the beam is not to be considered a limitation upon this invention.

The beam **40** may be substantially strengthened by embossing the sides of the lower portion **42** to form spaced outwardly extending reinforcement beads **47**. The beads **47** are elongated and their long axes are oriented vertically. The beads **36** are preferably aligned with the bosses **45**, thereby providing extra strength in the beam directly beneath each of the points of load transfer between the beam and the covering sheets secured to the beam.

When the beam is embossed to form the beads **47**, this operation is preferably carried out simultaneously with the shearing of the flat stock to form the bosses **45** and concavities **44**. The stock is then bent into the desired beam shape by suitable machinery such as a press brake.

While this invention has been illustrated primarily as applied to a roof, it will be recognized that both the beams and the sheet material may, with equal utility, be applied to side wall structures as a covering. This inven-

tion may be applied wherever it is desired to use a thin sheet material as a means of enclosing a structure either where it is desired to sustain substantial loads such as occur on roofs or where, as on side walls, it is desired to use a material which will materially add to the strength and rigidity of the structure and having no tendency to drum or oil can after application.

The primary advantage of this invention is the substantial gain in strength of the material, resulting from the compression of the webs to give them their concave configuration. In any particular application, this permits either a substantially higher loading of the finished structure or use of a substantially lighter gauge of material for a specified loading. In either case, an appreciable economy can be effected in the initial cost of the structure. The higher loadings permitted and the greater resistance to deflection permits the supporting beams to be spaced further apart. It has been found by test that, for a given load and a given gauge of material, the span between the supporting beams can be effectively increased or multiplied.

The placing of the ridges under tension contributes materially to the strength of the sheet. As a result the ridges have a materially increased resistance to failure due to collapse or indentation by externally applied blows. The added rigidity of the ridges or corrugations permits a higher corrugation to be utilized when desirable without failure by collapse and without increasing the gauge of the material. The ridge height of non-prestressed material of corresponding gauge must be restricted to substantially smaller dimensions to avoid crippling failure. The added ridge height thus available permits a highly favorable relocation in the moment of inertia of the overall sheet in addition to the structural benefits obtained by prestressing the webs. Thus, the beneficial results of the practice of this invention are cumulative.

Thus, in a particular structure, the number of supporting beams can be materially reduced. This reduces the overall cost of the supporting structure and the labor required to erect it. In side wall structures this is particularly important because the members used to support conventional sheet material are used in a quantity far in excess of that necessary to support the operating loads. These supports have to be closely spaced because of the tendency of the material to deflect under such conditions as high wind loading. With material of greater rigidity, the number of supports can be reduced and the total strength of the structure brought more in line with actual stress requirements. This, again, effects a material decrease in the initial cost of a structure erected with this material.

The shape of the ridges permits rough usage. Dents and punctures even of appreciable area either in the crown or sides of a ridge will not materially reduce the overall strength of the sheet. Unless they are numerous or particularly severe, they will not result in collapse of the ridge. This is an important factor because this type of material is frequently subjected to rough treatment both before and after installation.

While I have described a preferred embodiment of my invention, it will be recognized that modifications may be made without departing from the principle thereof. These modifications are to be considered as included in the hereinafter appended claims unless these claims by their language expressly state otherwise.

I claim:

1. A covering for a structure having spaced supports, said supports having outwardly projecting abutments thereon, said abutments being undercut at the base thereof, said covering comprising: a sheet having web portions integral with and separated by parallel inverted generally U-shaped ridge portions all projecting from one face thereof; said ridges when said covering is not installed on said supports being spaced a greater distance than the spacing between said abutments whereby when installed said web portions are compressed and arched oppositely to said ridges; said ridges being seated about said abutments with said sheet at the juncture of each of said webs and each of said ridges being pressed into the undercut portions of said abutments under the urging of said arched webs.

2. A covering for a structure having spaced supports, said supports having outwardly projecting abutments thereon, said covering comprising: a sheet having web portions integral with and separated by parallel inverted ridge portions having a semi-circular shape of uniform radius, and all projecting from one face thereof; said ridges when said covering is not installed on said supports being spaced a greater distance than when installed whereby when installed said web portions are compressed and arched oppositely to said ridges; said ridges tracing an arc of more than 180° when installed and having stresses received thereby more uniformly distributed through said arc; said ridges being seated about said abutments with said sheet at the juncture of each of said webs and each of said ridges being pressed against said abutments under the urging of said arched webs.

3. A covering for a structure having spaced supports, said supports having spaced, outwardly projecting abutments with undercut base portions separated by recessed portions extending below said undercut base portions, said covering comprising: a sheet having web portions which when the sheet is not installed on said structure are flat and normally lie in the same plane and are separated by a plurality of inverted, semi-circular U-shaped ridge portions all projecting from one face thereof, the ridge portions being spaced a distance greater than the spacing of said abutments; said webs when said sheet is installed on said structure being compressed and arched oppositely to said ridges, said ridges being seated about said abutments with said sheet at the juncture of each of said webs and each of said ridges being pressed against said undercut bases under the urging of said arched webs.

4. A covering for a structure having spaced supports, said supports having spaced, outwardly projecting abutments with undercut base portions separated by recessed portions extending below said undercut base portions, said covering comprising: a sheet having web portions which when the sheet is not installed on said structure are flat and normally lie in the same plane and are separated by a plurality of inverted, semi-circular U-shaped ridge portions all projecting from one face thereof, the ridge portions being spaced a distance greater than the spacing of said abutments; said webs when said sheet is installed on said structure being compressed and arched oppositely to said ridges, said ridges tracing an arc of more than 180°; said ridges being seated about said abutments with said sheet at the juncture of each of said webs and each of said ridges being pressed against said abutments under the urging of said arched webs.

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