

Jan. 31, 1967

W. D. BEHLEN

3,300,923

CORRUGATED METAL BUILDING AND BUILDING PANELS

Filed March 11, 1963

5 Sheets-Sheet 1

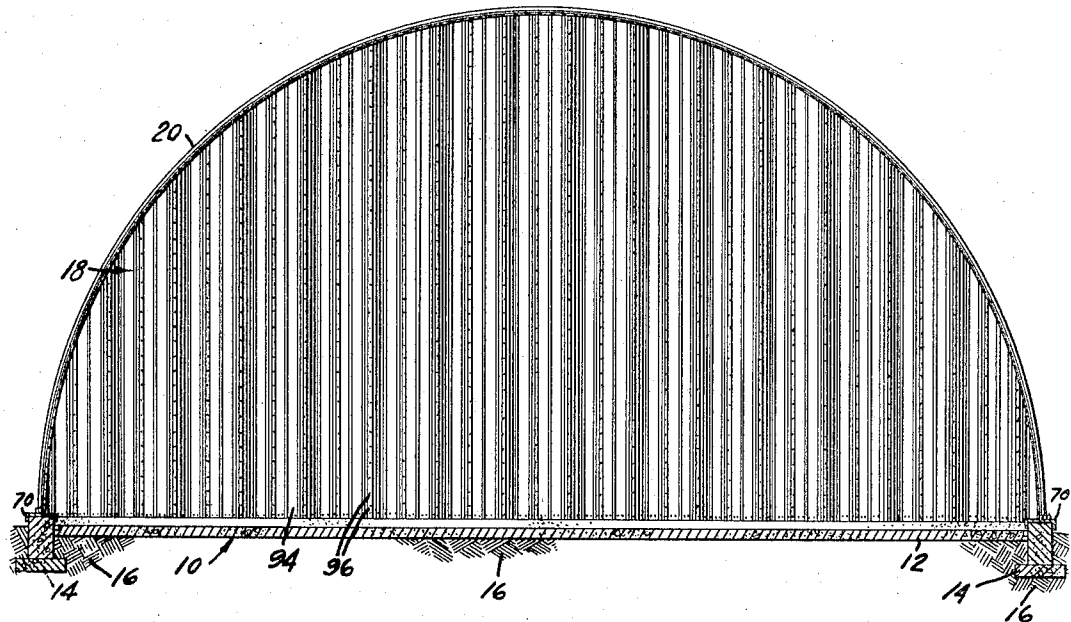


Fig. 1.

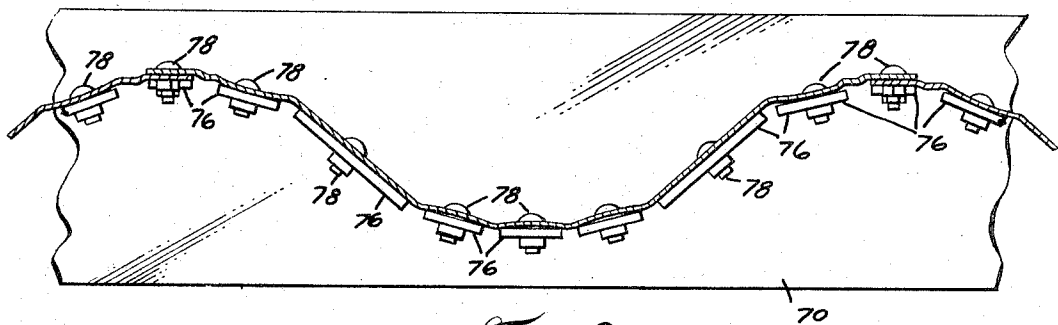


Fig. 2.

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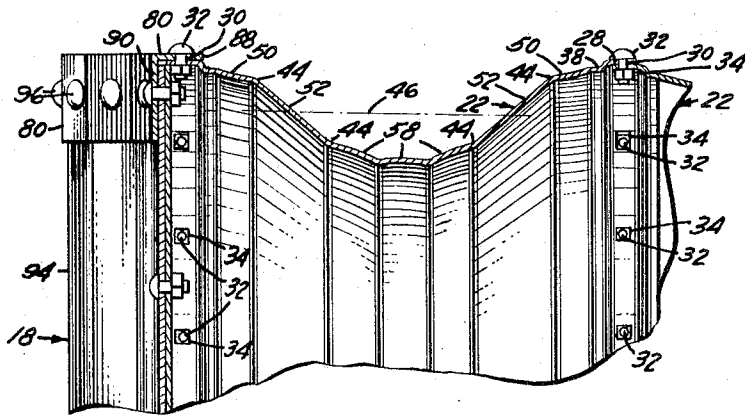


Fig. 3.

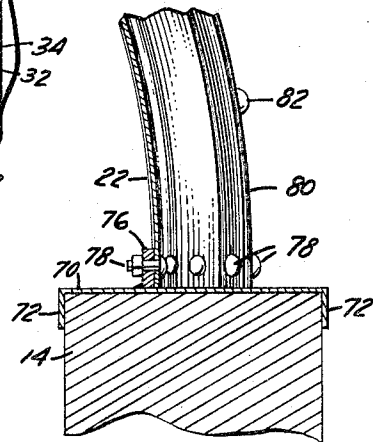


Fig. 4.

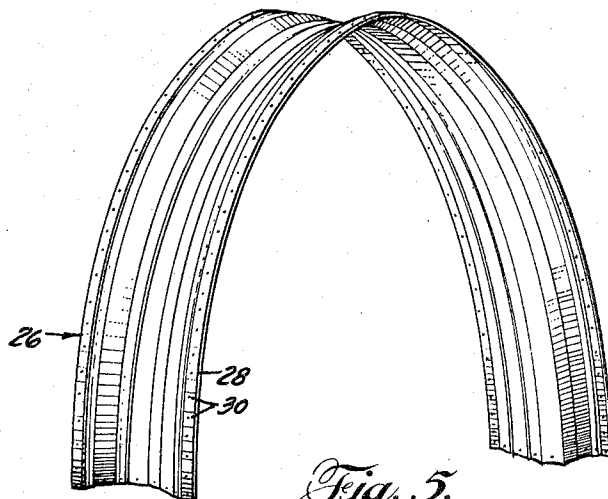


Fig. 5.

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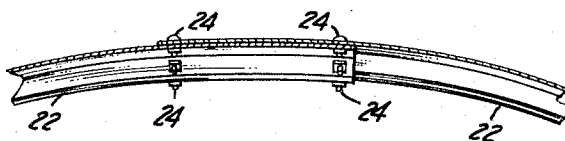


Fig. 6.

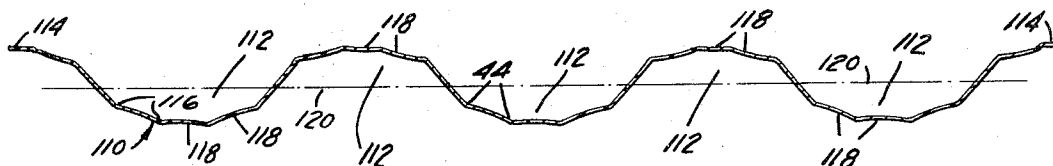


Fig. 7.

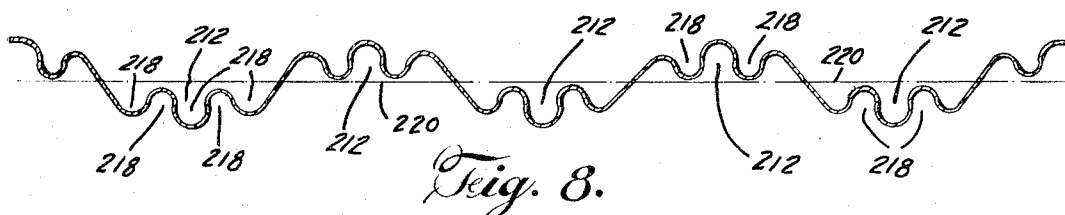


Fig. 8.

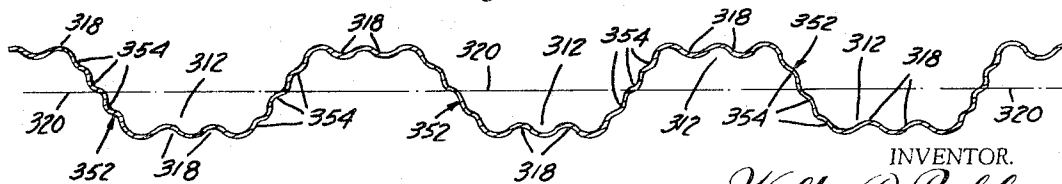


Fig. 9.

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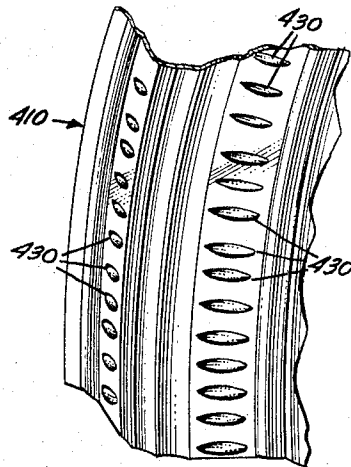
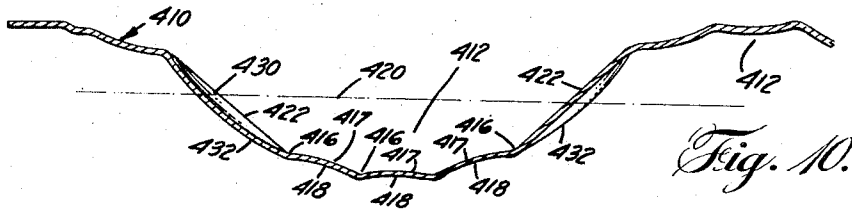
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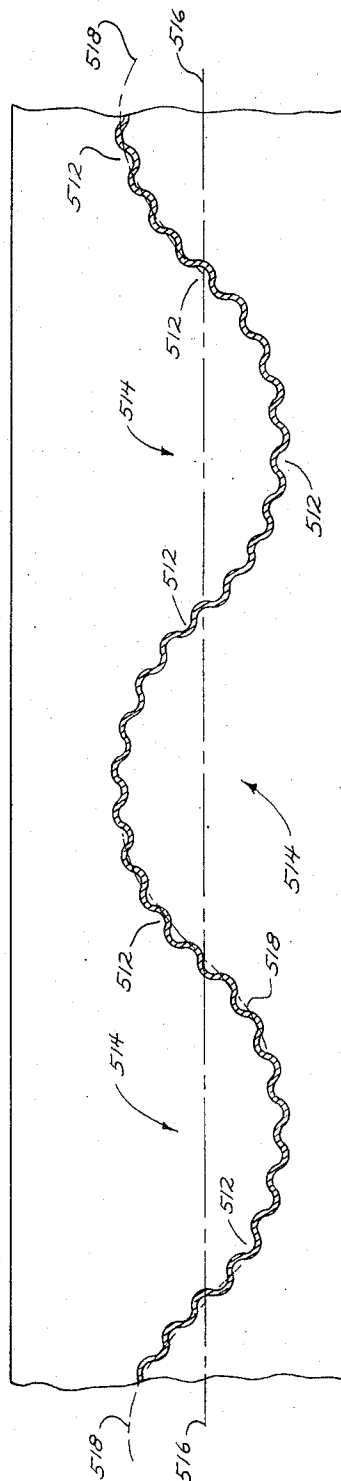


Fig. 12

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CORRUGATED METAL BUILDING AND BUILDING PANELS

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Filed Mar. 11, 1963, Ser. No. 266,131

1 Claim. (Cl. 52-245)

This is a continuation-in-part of application Serial No. 655,671, filed April 29, 1957, and now abandoned.

This invention relates to prefabricated metal buildings and more particularly it is an object of this invention to provide a building formed of a plurality of corrugated sheet metal panels which are curved lengthwise whereby they can be used to form a frameless building needing no roof supporting beams.

A particular object of this invention is to provide a building formed of curved panels which are curved lengthwise and which are of lighter gauge material than has been used heretofore for achieving maximum economy.

A further object of my invention is to provide a corrugated metal building panel comprised of a compound series of corrugations wherein each corrugation in each series of corrugations has a similar diameter.

A still further object of my invention is to provide a corrugated metal building panel that is economical of manufacture and refined in appearance.

These and other objects will be apparent to those skilled in the art.

Other and further objects and advantages of the present invention will be apparent from the following detailed description, drawings and claim, the scope of the invention not being limited to the drawings themselves as the drawings are only for the purpose of illustrating a way in which the principles of this invention can be applied.

Other embodiments of the invention utilizing the same or equivalent principles may be used and structural changes may be made as desired by those skilled in the art without departing from the present invention and the purview of the appended claims.

In the drawings:

FIGURE 1 is a vertical cross section taken transversely through an elongated building of this invention;

FIGURE 2 is a horizontal cross section taken through a side wall of the building of FIGURE 1;

FIGURE 3 is a vertical section taken longitudinally through the building of FIGURE 1 and showing in detail only a portion thereof at which roof sections meet the end wall;

FIGURE 4 is a vertical section taken transversely through a lower portion of the side wall of the building of FIGURE 1, a portion of the footing being broken away;

FIGURE 5 is a perspective view showing a modified form of a single panel to illustrate the curvature which can be placed in such a panel where desired;

FIGURE 6 is a cross sectional view showing the method of overlapping the ends of two roof panels of a modification of the building of FIGURE 1 in which more than one panel is used to span the distance from side to side across the top of the building;

FIGURE 7 is a transverse cross section taken through an elongated panel of a further modified form, only an edge portion of the panel of FIGURE 6 being shown for simplicity of illustration;

FIGURE 8 is a transverse cross section taken through an elongated panel of still a further modified form, only an edge portion of the panel of FIGURE 8 being shown for simplicity of illustration;

FIGURE 9 is a transverse cross section taken through an elongated panel of still a further modified form, only an edge portion of the panel of FIGURE 9 being shown for simplicity of illustration;

FIGURE 10 shows a further modification of the panels of this invention, the view showing in cross section an edge portion of a panel extending through one large corrugation;

FIGURE 11 is a perspective view of a portion of panel of the type shown in FIGURE 10; and

FIGURE 12 is a transverse cross section taken through an elongated panel of still a further modified form of my invention.

Referring to FIGURE 1, a building is there generally indicated at 10, having a foundation slab 12 and footings 14, extending above the ground 16.

The building 10 has two end walls, only one of which appears at 18 in the sectional view of FIGURE 1.

The end walls 18 are formed of corrugated panels 19 which are corrugated as seen in horizontal cross section and which can be bolted together at their sides.

The building 10 has an arcuate roof 20 which is composed of a plurality of elongated semi-circular roof panels 22 secured together at their ends, as best seen in FIGURE 6, by suitable bolts 24. The bolts can be in two rows extending transversely across the panels and are preferably arranged adjacent the ends of the respective panels.

It will be seen that what will be referred to as the roof 20 in this application serves as both a roof and side walls in combination as is suitable in uses where the side walls can incline inwardly and such a building is shown in FIGURE 1.

However it will be understood that the roof 20 shown in FIGURE 1 could be placed above side walls of the vertical kind, for example, the footings 14 could extend above the ground a considerable distance and form side walls of the building, while the roof 20 would then serve substantially as a roof only.

It will be seen that it is not necessary that the roof be made of panels attached end-to-end, but that a panel can be of such length that it extends completely across the roof in one piece and such a panel is shown at 26 in FIGURE 5.

Vertical side walls can also be a continuation of the curved panels themselves being left straight at the ends near the footings. Similarly, the wall panels disclosed herein have valuable applications as structural members even when they are straight and have not been curved at all.

With panels of the type shown at 26 in FIGURE 5, no overlapping of the ends is necessary and panels of this type need only to be attached to adjacent panels at their overlapping sides as later described.

When overlapping is used, two panels can be used to span across a roof and they can be overlapped at the center as in FIGURE 6 or else as many separate panels as desired can be used and overlapped at any places desired.

The panels 22 have edge portions 28 which are substantially flat as seen in cross section and as best seen in FIGURE 3. These edge portions are parallel with each other.

As best seen in FIGURES 3 and 5, the panels each have apertures 30 equi-distantly spaced apart from each other and extending along the side edges of the panels for receiving bolts 32 having nuts 34 which latter attach the side of one panel to the side of an adjacent panel when the edges of the panels are overlapped as best seen in FIGURE 3.

The material of a panel disposed between the edge portions 28 can be formed into a single large corruga-

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tion if desired or can be formed into multiple corrugations whereby it is wavy. An example of a single large-corrugation panel is shown in FIGURE 3 while in FIGURE 7 a multiple large-corrugation panel is shown. A row of single corrugation panels bolted side to side also form a wavy roof. Each wave I refer to as a large corrugation.

However the material in the large corrugations or waves so formed can be itself provided with many vertical sharp smaller corrugations or creases as best seen at 44 which divide the panel into separate portions which can be thought of as small corrugations.

A line can be seen at 46 in FIGURE 3 which represents the position of the neutral axis of the roof at the point of the cross section of FIGURE 3, whereby the construction can be compared to an I-beam in which portions seen at 50 and the edge portions 28, which are both disposed the farthest from the neutral axis 46, are comparable to a flange of an I-beam, whereas inwardly inclining portions 52 are comparable to the web of an I-beam. Other portions seen at 58 which are disposed the farthest from the neutral axis 46 and on the opposite side are comparable to the opposite flange of an I-beam.

By comparison with an I-beam it will be seen that the roof 20 has tremendous load-bearing strength as is more fully explained elsewhere.

Referring to FIGURE 4 it will be seen that a cap or sill member 70 is used to cap the top of the footing 14, the member 70 extending across the top and having flanges 72 extending downwardly on the inner and outer sides of the footing 14.

As best seen in FIGURE 2, a plurality of anchor flanges 76 are suitably secured to the cap 70 and extend upwardly therefrom. Bolts 78 extend through the lower edge of the lowermost panels of the roof and also extend through the anchor flange 76 for attaching the lower panels 22 to the footing 14 securely.

As best seen in FIGURE 3, an elongated wavy edge member 80 of the shape of a right angle in cross section is attached to the endmost panels of the roof by means of suitable bolts 32.

The member 80 has an arcuate flange 88 which overlaps the respective endmost roof panel 19 and has a wavy flange 90 which closely overlaps the panels of the end wall 18.

At their upper ends, the end wall panels 94 are attached to the roof panels 22, as best seen in FIGURE 3, and by means of the edge member 80, the side flange 90 of which is corrugated identically with the panels of the end wall 18.

The edge member 80 is secured to the end wall panels 94 by means of bolts 96 whereby the edge member 80 secures the end wall 18 to the roof by extending around the outer side of each.

It will be seen by referring to FIGURE 2 that the method of attaching the corrugated end wall panels 94 to the footing 14 can be the same as the method of attaching the roof panels to the footing. It will also be seen that if a cross section is taken adjacent the point of connection to the footing, the appearance of the cross section will be the same for both the end walls 94 and the combination sidewall and roof 20, as shown in FIGURE 2, whereby FIGURE 2 serves to illustrate both.

Referring to FIGURE 7 a single panel 110 having many large corrugations or waves 112 in it is shown. It will be seen that any number of waves or large corrugations 112 can be disposed between the side edges 114 of the panel.

Referring to FIGURE 7 it will be seen that the panel 110 has edge portions 114 which correspond to the edge portions 28 of the panel of FIGURE 5 and which are suitable for overlapping and bolting.

Between the edge portions 114 are many waves or large corrugations 112, five being shown in the illustration of FIGURE 7. Each of the large corrugations 112 has within it many small lengthwise corrugations or vertical

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creases 116 for greater strength. The more vertical creases 116 are used proportional to each larger corrugation 112, the greater strength the panel has. The material between each pair of adjacent vertical small corrugations 116 can also be called a small corrugation 118 if desired because each small corrugation 118 is preferably arcuate, having a slight convex curve on the side thereof that faces the neutral axis 120 of the panel. As shown in FIGURE 7, each arcuate corrugation 118 is of the same radius and length. The three corrugations 118 on one side of the neutral axis 120 are interconnected by a flat segment 118A, which crosses the neutral axis at an angle of approximately 45 degrees, to the next adjacent series of three arcuate corrugations 118 on the other side of the neutral axis.

Nothing is gained by having small corrugations or creases which are in excess of the equivalent of a 90° angle crease spaced not farther apart than twenty-four times the thickness of the material, and the corrugations of the modifications of FIGURES 2 and 7 have been than 90° bends. It is necessary to have the flat areas, if any, less than twenty-four times the thickness of the material.

More vertical creases will increase the strength of the section only up to the point where the creases are sufficient to "develop the section." Additional creases beyond that point only use additional material without an increase in strength. "Developing a section" means to give a piece of material such a shape in cross-section that it will resist a compression load beyond its elastic limit and will actually compress before buckling. In other words, the elongated panel, having small lengthwise corrugations in the larger corrugations, should have the combined corrugations of sufficient depth, contour and number and also the material of the panel should be of such strength and thickness that when the panel is subjected to a compression load beyond the elastic limit of the material of which it is made, the panel will compress more easily than it will buckle.

Referring to FIGURE 8, a further modification of the roof panel is there shown, this panel being numbered 210 and corresponding to the panel 110. It has waves or large concave corrugations 212, each of which have within them many smaller corrugations 218, the latter having concave sides facing the neutral axis indicated by dotted line 220.

By comparison it would be seen that roof 20 has tremendous load-bearing strength even though made of light weight sheet metal. This is made possible because the small corrugations, which are within the large corrugations, are so formed or spaced that no flat transverse spaces remain in the large corrugations (except perhaps in the webs) which are wider than twenty-four times the thickness of the sheet metal of which the panel is made.

It will be seen that the smaller corrugations 218 are of much greater depth than the corrugations 118, each of the corrugations 218 containing a complete turn-back of the material upon itself to form a U-shaped small corrugation.

It will be seen that the essence of the cross-sectional shapes of FIGURES 7 and 8 is that this is the first use of small corrugations within large corrugations or waves.

I have found that the panel of FIGURE 8 will withstand more pressure in compression per thickness of material, without buckling, than the panel of FIGURE 7, whether the panel is curved lengthwise or is straight lengthwise and my invention embraces both panels which are straight lengthwise and those which are curved lengthwise, where both have cross sections defining small corrugations within large ones, even though made of light gauge sheet metal. This is made possible because the small corrugations (within the large corrugations) are so formed or spaced that no flat transverse spaces remain anywhere in the large corrugations (except perhaps in the webs) which are wider than twenty-four times the thickness of the sheet metal of which the panel is made.

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A cross sectional shape of a piece of material which gives adequate resistance to buckling during forming likewise gives adequate resistance to buckling under load and the resistance to buckling during forming and the resistance to buckling under the load are the same for a given piece of material.

It is important to remember that no flange ever will buckle in lengthwise forming and bending or in structural use if the flange has small corrugations, or creases, which are the equivalent in their properties to a right angle bend spaced not farther apart than twenty-four times the thickness of material.

Also the lighter the gauge of the material is, the smaller the depth of the large corrugation must be from the neutral axis or the smaller and closer together the small corrugations must be to prevent buckling during formation of the lengthwise curvature during manufacture.

I have found that the presence of smaller corrugations within the large ones greatly increases the possibility of forming a panel of a given gauge and a given depth of large corrugation to a given radius of curvature without buckling. This discovery has led to the possibility of buildings of greater economy of construction from fewer pounds of steel than was heretofore possible.

The small corrugations of creases 116 and concave small corrugations 118 of FIGURE 7 and the small corrugations 212 of FIGURE 8 are very important to formation of a lighter stronger panel without buckling during curving the panel and during use. The panel of FIGURE 8 is not substantially stronger than the panel of FIGURE 7 because the small corrugations of the panel of FIGURE 8 approach so close to the neutral axis 220 of the panel as to make those parts of the corrugations of little value structurally.

The web angle of approximately 45° with respect to the neutral axis, as best seen in FIGURE 7, is important as it provides the best combination of area coverage and corrugation depth in a panel of a given area coverage or "flat width" as it is called.

Referring to FIGURE 9, a panel is there shown having large corrugations 312 smaller corrugations 318 and a neutral axis 320, these parts corresponding to the respective parts 112, 218 and 220 of the panel of FIGURE 8. However it will be seen that in the panel of FIGURE 9 the corrugations 318 are spaced a considerable distance from the neutral axis 320 and much farther than the spacing of the closer corrugations 218 of FIGURE 8 to the neutral axis 220 of FIGURE 8. For this reason the panel of FIGURE 9 would be stronger than the panel of FIGURES 7 and 8.

Referring again to FIGURE 9, it will be seen that web portions 352 corresponding to the web portions 52 of the panel of FIGURE 3 are provided with a plurality of corrugations 354. These corrugations 354 in the webs strengthen the panel as is necessary in some cases to prevent diagonal buckling or wrinkles from developing during lengthwise curving of the panels.

Referring to FIGURES 10 and 11 a further modification of the building panels of this invention is depicted at 410, only an edge portion of the panel being shown. It is understood that the panel 410 has many large corrugations 412, only one of which is shown in FIGURE 10, as only a broken away portion of the complete panel is shown.

The panel 410 also has smaller corrugations or creases 416, the creases 416 separating portions 417 of the panel from each other, the latter portions 417 being concave on those sides thereof which are spaced farthest from a neutral axis 420 and concave on those sides thereof which are spaced closest to the neutral axis 420, whereby the concave sides 418 themselves form small corrugations.

It can be seen that the portions 417 of the panel which are disposed between the creases or small corrugations 416 can be thought of collectively as a section of the panel which section is spaced farther from the neutral

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axis of the panel than are the web portions 422 of the panel which will now be described.

The web portions 422 of the panel are disposed closer to the neutral axis 420 than the other portions of the panel whereby the portions 417 between the creases 416 can be collectively thought of as the flange section of the panel and the portions 422 can be thought of as the web sections of the panel.

It will be seen that each web section 422 lies partially on one side and partially on the other side of the neutral axis 420.

In accordance with my invention the web 422 can be corrugated cross-wise with respect to the lengthwise large corrugations 412. As best seen in FIGURES 10 and 11, this is preferably accomplished by forming indentations 430 in the metal on one side of the web portions 422 and at spaced intervals along the length of the panel whereby protrusions 432 exist on the opposite side of the panel.

The protrusions 422 extend transversely of the lengthwise corrugations 412 and are elongated, being wider at their centers and tapering to narrower ends whereby they are of elongated almond shape, the narrower ends being almost pointed.

The indentations 422 are likewise elongated, extending transversely of the large corrugations 412, and are each wider at their center tapering to narrower ends which are almost pointed.

As thus described, rows of indentations and protrusions are defined which are best seen in FIGURE 11. The indentations are preferably equidistantly spaced apart from each other and are relatively closely spaced apart as best seen in FIGURE 7.

The elongated almond corrugations or indentations 430 also taper from a greatest depth and width at the mid-point of the web to a depth and width of zero near each flange. The cross corrugations 430 would not contribute to columnar strength of the panel, but would prevent the wrinkling of the webs during lengthwise curving, as is a serious problem.

I have found that a panel having three main corrugations per side each three inches deep as shown in FIGURE 7, can be successfully curved lengthwise to a fifteen foot radius without unwanted transverse compression buckling from 20 gauge steel.

I have found that when the panels are formed of approximately 20 gauge steel with the large lengthwise corrugations being of an average depth of approximately three inches that the panels can be curved to a radius of curvature of fifteen feet without any danger of buckling or unwanted crosswise corrugations, and that the resulting product is capable of withstanding heavy compression and bending loads when used as a building member.

It will be seen that buckling on the top side of the roof is a main concern in the center of the roof whereas buckling of the under side is the main concern half-way down the side of a roof.

In the formation of the building it will be seen that the panels can be easily shipped and then assembled at the point of construction.

The building of FIGURE 1 can be of a width that is twice the height whereby the roof is in an exact semi-circle. However it could also be made of a shape such that the width is greater than the height whereby it is less than a semi-circle where desired. Also, a parabolic shape can be used.

It will be further seen that this invention has provided light gauge panels which are both corrugated lengthwise (by which I mean are provided with elongated corrugations extended the length of the material) and are also curved lengthwise and which have other uses than those described herein.

A most efficient panel 510 is shown in FIGURE 12. Panel 510 has a plurality of small alternately disposed arcuate corrugations 512 which extend in uninterrupted fashion from one end of the panel to the other. The panel

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is then formed into a plurality of larger alternately disposed arcuate corrugations 514 which also extend in uninterrupted fashion from one end of the panel to the other. The neutral axis 516 of corrugations 514 is straight, and the arcuate neutral axis 518 of the corrugations 512 forms a trigonometric sine wave with the axis 516. The radii of corrugations 512 are constant and identical. Similarly, the radii of corrugations 514, as measured on the arcuate neutral axis 518 of corrugations 512, are all constant and identical. Panel 510 can be either straight or curved, and the corrugations 512 and 514 extend in uninterrupted fashion from one end of the panel to the other. The section developed by these series of corrugations wherein each corrugation has a constant radius, and each corrugation in each series of corrugations is identical, provides a panel of maximum strength. In addition, the panel is easier to manufacture with this type corrugated structure.

From the foregoing description, it is thought to be obvious that a corrugated metal building and building panels constructed in accordance with my invention is particularly well adapted for use, by reason of the convenience and facility with which it may be assembled and operated, and it will also be obvious that my invention is susceptible of some change and modification without departing from the principles and spirit thereof, and for this reason I do not wish to be understood as limiting myself to the precise arrangement and formation of the several parts herein shown in carrying out my invention in practice, except as claimed.

Some changes may be made in the construction and arrangement of my corrugated metal building and building

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panels without departing from the real spirit and purpose of my invention, and it is my intention to cover by my claim, any modified forms of structure or use of mechanical equivalents which may be reasonably included within their scope.

I claim:

An article of manufacture, comprising, an elongated panel, a plurality of alternately disposed arcuate corrugations in said panel extending in continuous and uninterrupted fashion from one end of said panel to the other, said panels being bent into a plurality of alternately disposed larger arcuate corrugations which are co-extensive with said first-mentioned corrugations and which also extend in continuous and uninterrupted fashion from one end of said panel to the other; the arcuate neutral axis of said first-mentioned corrugations forming a trigonometric sine wave with respect to the straight neutral axis of said larger corrugations, said panel being longitudinally curved.

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