June 12, 1962 E. F. HAUER 3,038,278

WALL CONSTRUCTION

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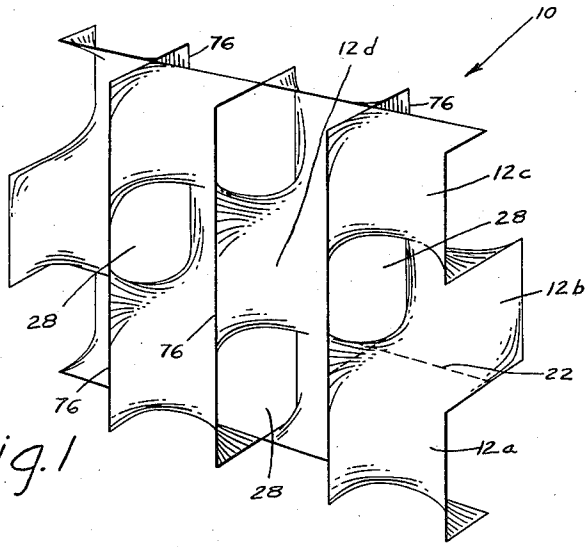


Fig. 1

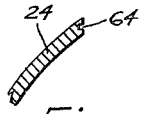


Fig. 3

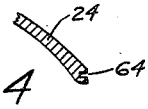


Fig. 4

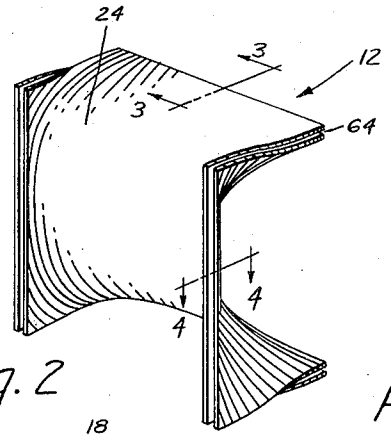


Fig. 2

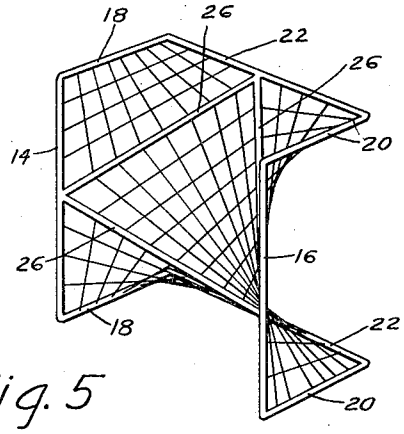


Fig. 5

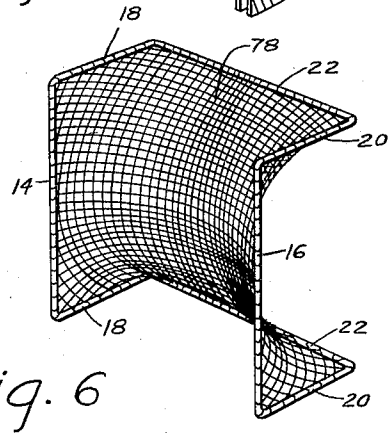


Fig. 6

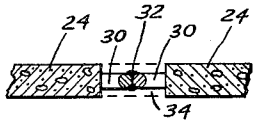


Fig. 7

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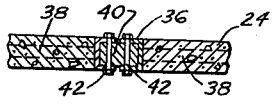


Fig. 8

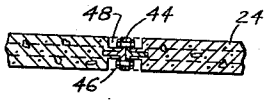


Fig. 9

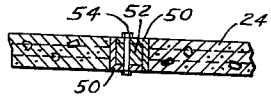


Fig. 10

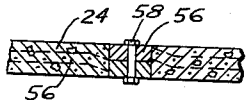


Fig. 11

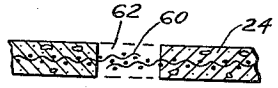


Fig. 12

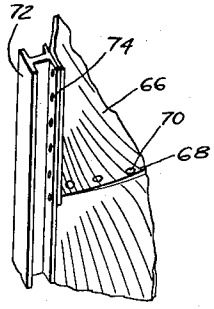


Fig. 13

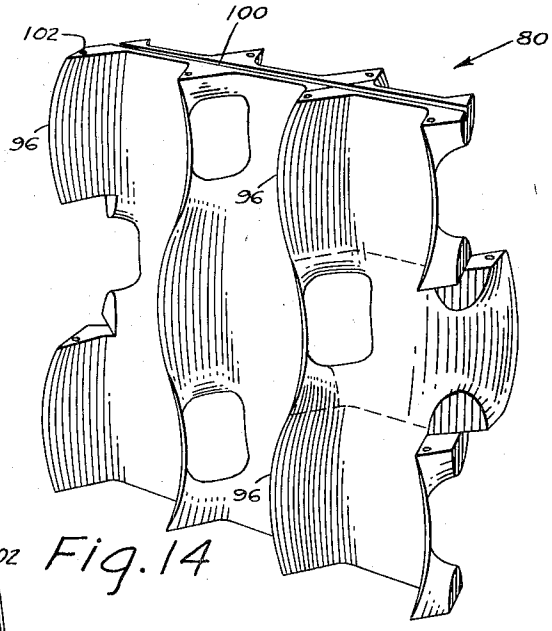


Fig. 14

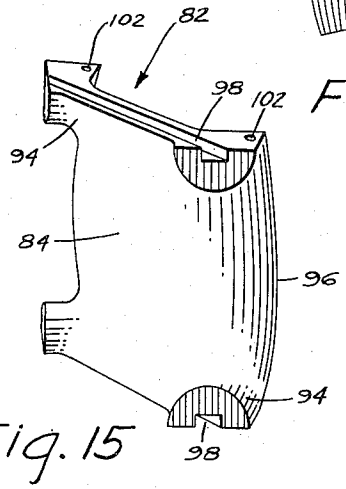


Fig. 15

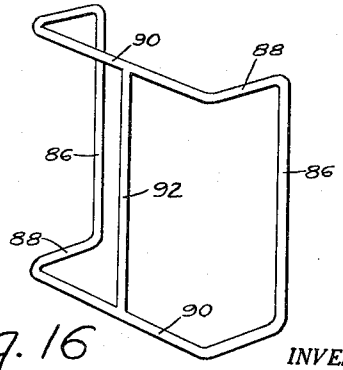


Fig. 16

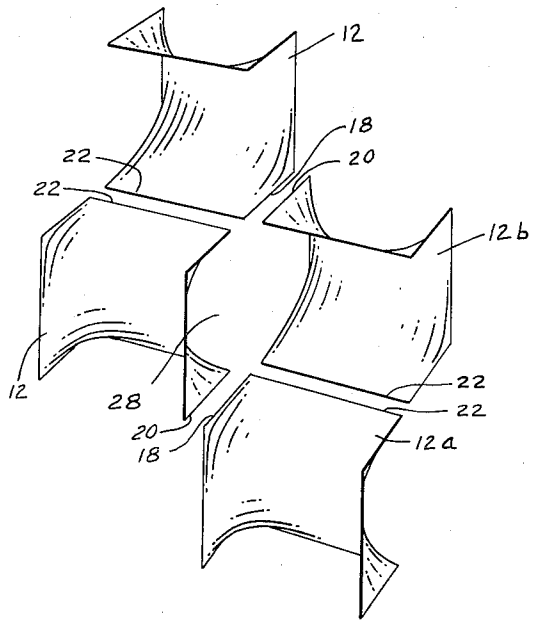
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Fig. 17



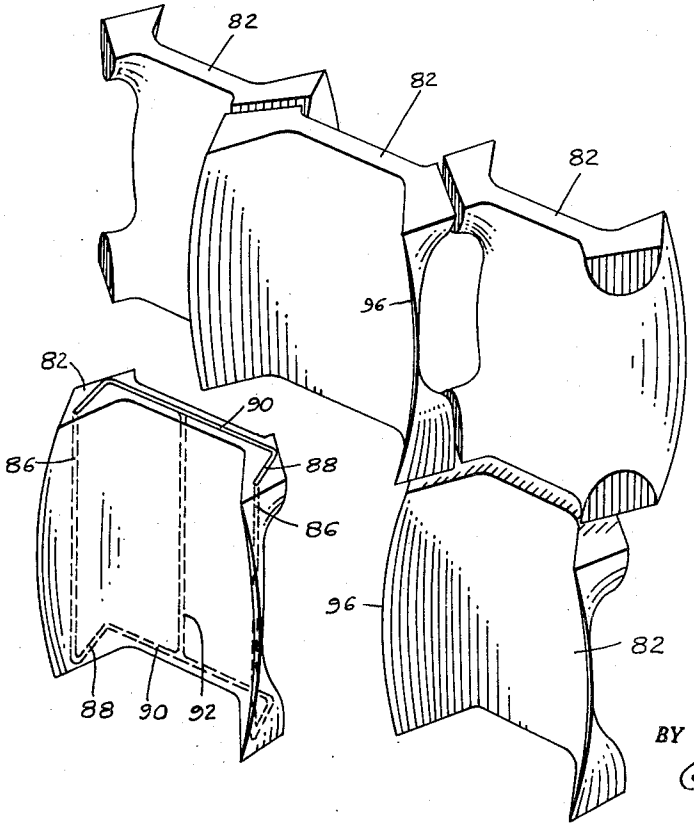


Fig. 18

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United States Patent Office 3,038,278
Patented June 12, 1962

3,038,278

WALL CONSTRUCTION

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Filed Aug. 6, 1958, Ser. No. 753,446
6 Claims. (Cl. 50—262)

The present invention relates generally to an architectural construction and is more particularly concerned with the provision of a novel and improved wall or surface construction.

A primary object of the instant invention is the provision of a structural assembly or system which can be used either as a horizontal spanning element or as a vertical wall.

Another important object of my invention is the provision of a structural assembly which provides highly effective fenestration where indirect or diffused light is desired.

A further object of this invention is the provision of a wall construction wherein the structural or strength-imparting components are integrated with an enclosing membrane or skin to provide a highly effective unit possessing a high degree of structural strength, while at the same time utilizing a reduced amount of construction material, particularly as opposed to the prior art constructions wherein a given wall generally consists of strength-imparting trusses in combination with separate curtain walls or roof skin, the latter elements functioning to provide the enclosing medium.

Another object of my invention is the provision of a wall construction which may be manufactured by the fabrication of similar or identical modular units, it being possible to fabricate the completed wall either on location or beforehand.

Still another object of my invention is the provision of an integrated structural and enclosing wall which possesses great strength while utilizing a relatively small amount of material, which has a reduced dead load, which diffuses light in a highly effective fashion and which at the same time provides a construction of highly attractive and pleasing appearance.

Other objects, features and advantages of the invention will become apparent as the description thereof proceeds when considered in connection with the accompanying illustrative drawings.

In the drawings which illustrate the best mode presently contemplated by me for carrying out my invention:

FIG. 1 is a diagrammatic view of a wall section embodying the preferred form of my invention;

FIG. 2 is a perspective view, on an enlarged scale, of a modular unit that may be used in the manufacture of the instant invention;

FIG. 3 is a fragmentary section taken on line 3—3 of FIG. 2;

FIG. 4 is a fragmentary section taken on line 4—4 of FIG. 2;

FIG. 5 is a perspective view, on an enlarged scale, of a frame which illustrates the geometrical configuration of the individual modular units;

FIG. 6 is a perspective view, on an enlarged scale, illustrating one method of manufacturing the individual modular units;

FIGS. 7 through 12 are fragmentary sectional views, on an enlarged scale, illustrating various structural connections between adjacent modular units constructed of concrete or shotcrete;

FIG. 13 is a fragmentary perspective view, on an enlarged scale, illustrating a structural arrangement and connection which may be used where the modular units are of sheet metal;

FIG. 14 is a perspective view of a slightly modified wall construction;

FIG. 15 is a perspective view, on an enlarged scale, illustrating one of the individual modular units which may be utilized in the manufacture of the wall illustrated in FIG. 14;

FIG. 16 is a perspective view, on an enlarged scale, of a frame which illustrates the configuration of the modular unit disclosed in FIG. 15;

FIG. 17 is an exploded diagrammatic view of the wall section shown in FIG. 1; and

FIG. 18 is an exploded perspective view of the wall section shown in FIG. 14.

It has been found desirable to provide a structural wall consisting of a continuous membrane. Thus, the web conventionally used in trusses to resist shear and to unify the flanges is replaced by an integrated surface which makes the application of separate curtain walls for roof skin unnecessary. By combining the strength-imparting structure and the enclosing medium into one, numerous advantages are obtained, such as reduction in dead load, saving in material, and the integration of architecture and structure whereby a unique and attractive appearance may be achieved. In addition, as will hereinafter become apparent, symmetrically positioned openings are inherently present in the instant structural assembly whereby effective fenestration and diffusion of light is obtained.

It will be understood that the term "wall construction" as used herein is to be broadly construed, and it covers horizontal and angularly disposed surfaces as well as vertical walls.

Referring now to the drawings, and more particularly to FIG. 1 thereof, there is shown a section of a wall constructed in accordance with the instant invention, generally designated at **10**. As will be noted, wall **10** comprises a plurality of identically curved portions, one of which is illustrated at **12**, note FIG. 2. In most instances the wall **10** is made up of a plurality of individual modular units **12** integrated in a manner hereinafter to be described. In some cases, however, the wall **10** may be integrally constructed rather than fabricated from individual modular units, but in order to understand the basic concepts and characteristics of wall **10**, it is necessary to analyze the configuration of one of the curved portions which make up the completed wall, and hence the modular unit **12** will now be described in detail.

Referring to FIGS. 5 and 6, it will be seen that the peripheral edge of one of the modular units **12** defines a pair of parallel, equi-length chords **14** and **16**, each of which has at its opposite extremities perpendicularly extending struts **18** and **20**. The struts **18** and **20** all extend in the same direction from the plane defined by chords **14** and **16** and are of equal length. Adjacent struts **18** and **20** are connected at their free extremity by cross bars **22**, and the configuration defined by chords **14**, **16**, struts **18**, **20**, and cross bars **22**, represents the shape of the periphery of each modular unit **12**. The modular unit itself actually comprises a membrane **24** which represents the minimum surface capable of spanning the peripheral edge configuration just described.

The membrane **24** may be constructed by a variety of manufacturing techniques, hereinafter to be more fully described, and it will be understood that said membrane may be of any suitable structural material, such as metallic sheet, cast concrete, shotcrete (sprayed concrete), structural plastic or plaster. As will be readily seen, particularly in FIGS. 2 and 6, the membrane **24** is characterized by a double or compound curvature, which curvature closely approximates a hyperbolic paraboloid. Actually, the minimal surface spanning the peripheral edge configuration illustrated in FIGS. 5 and 6 will automatically assume this desired compound curvature, and as

evidence of the fact that membrane 24 closely approximates a hyperbolic paraboloid, lines 26 (FIG. 5) joining the mid points of chords 14 and 16 with the mid points of cross bars 22 to provide a diamond-like configuration will automatically be straight lines. The portion of membrane 24 which is enclosed by imaginary lines 26 actually is a true hyperbolic paraboloid, and while the four corner portions of membrane 24 (the portions outside the diamond defined by imaginary lines 26) are not actually true hyperbolic paraboloids, they retain the double curvature which is the essential and basic characteristic of such a configuration. The importance of the foregoing is that it is a well-known structural fact that a curved surface in the form of a hyperbolic paraboloid possesses maximum strength for a given weight and material since any stresses or strains imparted to such a curved surface will be equally distributed, and there will be no localized build-up of stresses and strains such as causes fatigue failure of truss systems and the like. Thus, the modular unit 12 with its highly specific curved membrane 24 represents one of the basic and salient concepts of the instant invention.

When integrating the modular units 12 to provide wall 10, the adjacent units are reversely positioned with respect to each other, as shown most clearly in FIG. 1. Thus, if unit 12*a* is positioned in the manner illustrated, then adjacent unit 12*b* extends in the opposite direction, as will be clearly seen, while unit 12*c* assumes the same relative position as unit 12*a*. It will therefore be seen that the parallel chords of the various units cooperate to define two planes parallelly spaced from each other and representing the inner and outer surfaces of the completed wall. At the same time, the cross bars 22 define a third plane located intermediate the two aforesaid planes and also parallelly disposed with respect thereto. Actually, any single modular unit, such as unit 12*d*, for example, is surrounded on its four sides with units extending in the opposite direction. When the various modular units 12 are integrated in the manner aforesaid to provide the completed wall 10, aligned openings 28 will automatically be established, and since said openings extend in a plane substantially perpendicular to the general plane of the overall wall, it follows that light passing through the wall 10 will be well diffused, said diffusion being further enhanced by the curvature of the membranes 24. It will be understood that the openings 28 may be covered by suitable glass panels or the like if it is desired to provide a complete and air-tight enclosure.

Where the individual modular units 12 are constructed of cast concrete, plaster or the like, numerous structural techniques may be employed for integrating and joining abutting units, it being apparent that adjacent units will make abutting engagement along their edges 18, 20 and 22. FIGS. 7 through 12 illustrate some of these various techniques and will now be described. In FIG. 7 the abutting membranes 24 are provided with outwardly extending metallic frames or bars 30 which are brought into engagement with each other and then are welded such as at 32. The connection may then be filled in with concrete as at 34 to provide a continuous flush surface.

In FIG. 8 the abutting membranes are provided at their edge portion with oppositely disposed metallic channels 36 secured to the membranes by any suitable means, such as by having integral extensions imbedded therein as at 38. The channels 36 receive therein a metallic spline or bar 40 and then bolts 42 extend thereacross to integrate the structure.

In FIG. 9 the abutting membranes are provided at their edge portions with imbedded T bars 44 making face-to-face contact with each other as shown. The flat surfaces of the T bars are then secured to each other in any desirable way, such as by bolts 46 or the like. The connection is then filled in as at 48 to provide a flush, continuous surface. In FIG. 10 the membrane edges are provided with imbedded metallic L-channels 50 which receive therein a metallic spline or bar 52. The L-channels are then integrated by means of a cross bolt 54.

In FIG. 11 the abutting edges are provided with imbedded metallic extensions 56 which overlie each other and are then bolted together as at 58. In FIG. 12 the abutting edges are provided with imbedded wire mesh 60 which overlaps and is then filled in with concrete or shotcrete as at 62 to provide a continuous, flush surface.

In order to further strengthen the completed wall 10 where the latter is formed by the integration of a plurality of cast concrete modular units as described supra, the individual modular units are cast with peripheral channels 64 as shown clearly in FIGS. 2 through 4. Elongated metallic strengthening rods (not shown) may then be positioned in said aligned channels to enhance the rigidity and shear resistance of wall 10.

Referring to FIG. 13, a connection is shown wherein the individual modular units are constructed of sheet metal 66. In such a situation, the abutting edges of adjacent units are overlapped as at 68 and then secured by any desirable means, such as rivets 70, spot welding or the like. In order to strengthen the completed wall, I-beams 72 are secured to the aligned chord edges of adjacent modular units, as by rivets 74. It will be understood that the beams 72 extend completely across the completed wall 10, and, viewing FIG. 1, said beams would extend along the lines indicated by reference character 76.

In some instances, it is desirable to construct the wall 10 on site as opposed to fabrication of the wall from modular units as afore described. In such a situation, a truss network comprising chords 14 and 16, struts 18 and 20, and cross bars 22, is constructed and then wire mesh such as shown at 78 in FIG. 6 is secured to the framework to provide a foundation for the continuous wall surface. Shotcrete is then sprayed on to the wire mesh, thereby forming the completed wall.

In FIGS. 14 through 16 a slightly modified form of the instant invention is disclosed, the completed wall 80 being constructed by the integration of identical modular units 82. Although membrane 84 of modular unit 82 is somewhat similar to the aforedescribed membrane 24, it does differ in certain respects. First of all, membrane 84 is the minimum surface covering the configuration illustrated in FIG. 16, said configuration comprising parallel chords 86, struts 88 and cross bars 90, all similar to the configuration which defines the aforediscussed membranes 24, but further including an additional chord 92 joining the mid points of cross bars 90. In addition, membrane 84 is thickened at its corner portions as at 94 and the chord edges of said membrane curve outwardly as at 96 rather than having the straight edges which characterize membrane 24. It will be understood that the curved extensions 96 are primarily for shading purposes, and, in fact, all of the differences which exist in modular unit 82 over the preferred unit 12 are for reasons of appearance and light effect. As will be noted, each of the units 82 is provided with end channels 98 which align to provide a single channel 100 when the units are integrated to form a complete wall, as shown most clearly in FIG. 14. The units 82 are further provided with elongated bores 102 which extend in a direction transverse to that of channels 98, it being understood that said bores also align with those of adjacent units when said units are integrated. Thus, the channels 98 and bores 102 provide means whereby wall 80 may be strengthened and integrated, and more specifically, elongated strengthening rods (not shown) are inserted in said channels and bores to integrate adjacent units and also to impart greater rigidity and shear resistance to the completed wall.

It will be understood that the frame illustrated in FIG. 16 has been shown primarily as a means for defining and describing the configuration of modular unit 82. It is completely optional as to whether a physical frame of this configuration be incorporated in each modular unit,

and in most cases such a frame would not be utilized. If for any reason, such as strengthening purposes, it is desired to actually imbed a frame in this configuration in the modular unit, it would be positioned therein the manner indicated in FIG. 18.

While there is shown and described herein certain specific structure embodying the invention, it will be manifest to those skilled in the art that various modifications and rearrangements of the parts may be made without departing from the spirit and scope of the underlying inventive concept and that the same is not limited to the particular forms herein shown and described except in so far as indicated by the scope of the appended claims.

I claim:

1. A wall construction comprising a plurality of identical modular units, each of said units comprising a curved portion, the peripheral edge of which defines a configuration equal to that which would be established by a pair of equi-length, parallel chords, equi-length struts extending one from each extremity of said chords in the same direction from the plane defined by said chords and perpendicular thereto, and bars bridging the struts of one chord with the adjacent struts of the other chord at the free extremities of said struts, and means connecting said modular units to each other so as to provide aligned horizontal and vertical rows, each unit being reversely positioned with respect to its two contiguous horizontally aligned units and its two contiguous vertically aligned units, the adjacent bridging bar edges of adjacent vertical units and the adjacent strut edges of diagonally adjacent units being in engagement with each other, each of said curved portions representing the minimum surface capable of completely spanning the configuration defined by the peripheral edge of each unit.

2. A wall construction comprising an undulating, rigid wall having a plurality of identical curved portions, each of said curved portions representing the minimum surface capable of spanning a configuration equal to that which would be established by a pair of equi-length, parallel chords, equi-length struts extending one from each extremity of said chords in the same direction from the plane defined by said chords and perpendicular thereto, and bars bridging the struts of one chord with the adjacent struts of the other chord at the free extremities of said struts, said curved portions being arranged in aligned horizontal and vertical rows, each portion being reversely positioned with respect to its two contiguous horizontally aligned portions and its two contiguous vertically aligned portions, the adjacent bridging bar edges of adjacent vertical portions and the adjacent strut edges of diagonally adjacent portions merging with each other, the reverse positioning of adjacent horizontal portions automatically providing a plurality of symmetrically arranged and staggered openings in said wall, which openings extend in a plane substantially perpendicular to the plane in which said wall extends.

3. A modular unit for use in the construction of a self-supporting wall, said unit comprising a rigid, curved portion, the peripheral edge of which defines a configuration equal to that which would be established by a pair of equi-length, parallel chords, equi-length struts extending one from each extremity of said chords in the same direction from the plane defined by said chords and perpendicular thereto, and bars bridging the struts of one chord with the adjacent struts of the other chord at the free extremities of said struts, said curved portion representing the minimum surface capable of completely spanning the configuration defined by the peripheral edge of said unit.

4. A wall construction comprising a plurality of identical modular units, each of said units comprising a curved portion which represents the minimum surface capable of completely spanning a configuration equal to that which would be established by a pair of equi-length, parallel chords, equi-length struts extending one from each extremity of said chords in the same direction from the plane defined by said chords and perpendicular thereto, and bars bridging the struts of one chord with the adjacent struts of the other chord at the free extremities of said struts, and further comprising a third chord interconnecting the midpoints of said bridging bars, and means connecting said modular units to each other so as to provide aligned horizontal and vertical rows, each unit being reversely positioned with respect to its two contiguous horizontally aligned units and its two contiguous vertically aligned units, the adjacent bridging bar edges of adjacent vertical units and the adjacent strut edges of diagonally adjacent units being in engagement with each other.

5. A wall construction comprising an undulating, rigid wall having a plurality of identical curved portions, each of said curved portions representing the minimum surface capable of spanning a configuration equal to that which would be established by a pair of equi-length, parallel chords, equi-length struts extending one from each extremity of said chords in the same direction from the plane defined by said chords and perpendicular thereto, and bars bridging the struts of one chord with the adjacent struts of the other chord at the free extremities of said struts, and further comprising a third chord interconnecting the midpoints of said bridging bars, said curved portions being arranged in aligned horizontal and vertical rows, each portion being reversely positioned with respect to its two contiguous horizontally aligned portions and its two contiguous vertically aligned portions, the adjacent bridging bar edges of adjacent vertical portions and the adjacent strut edges of diagonally adjacent portions merging with each other, the reverse positioning of adjacent horizontal portions automatically providing a plurality of symmetrically arranged and staggered openings in said wall, which openings extend in a plane substantially perpendicular to the plane in which said wall extends.

6. A modular unit for use in the construction of a self-supporting wall, said unit comprising a rigid curved portion which represents the minimum surface capable of completely spanning a configuration equal to that which would be established by a pair of equi-length, parallel chords, equi-length struts extending one from each extremity of said chords in the same direction from the plane defined by said chords and perpendicular thereto, and bars bridging the struts of one chord with the adjacent struts of the other chord at the free extremities of said struts, and further comprising a third chord interconnecting the midpoints of said bridging bars.

References Cited in the file of this patent

UNITED STATES PATENTS

1,154,254	Lachman	Sept. 21, 1915
2,436,543	Blaski	Feb. 24, 1948

FOREIGN PATENTS

991,704	France	June 27, 1951