Sept. 7, 1943. C. MACKINTOSH 2,329,068

BUILDING BRACE

Filed Sept. 25, 1942 3 Sheets-Sheet 1

FIG. 1.

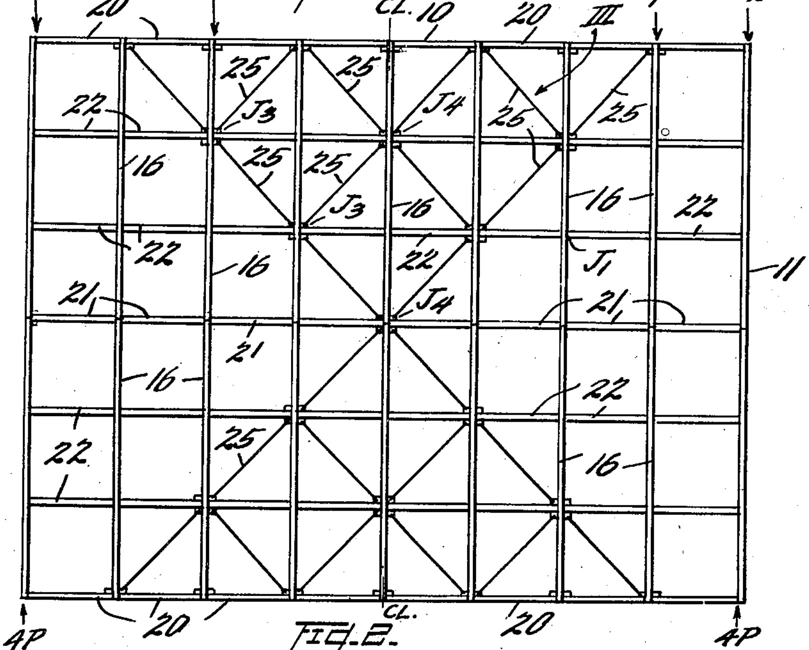


FIG. 2.

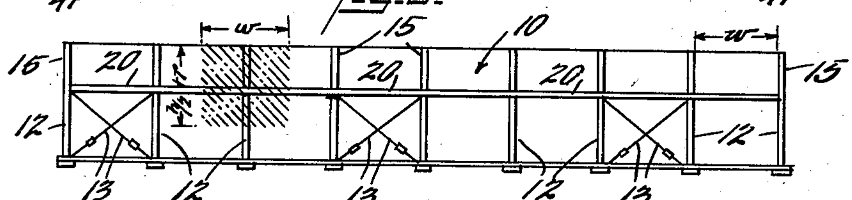


FIG. 3.

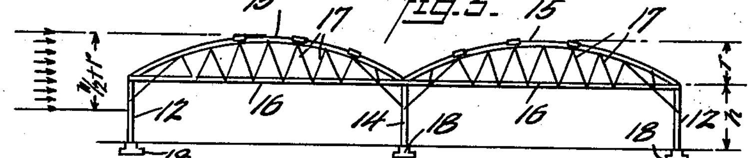


FIG. 4.

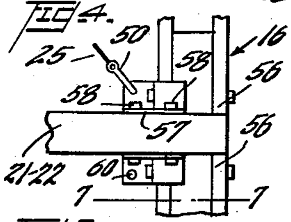


FIG. 5.

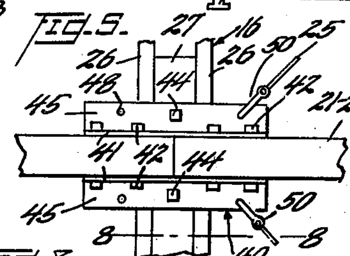


FIG. 6.

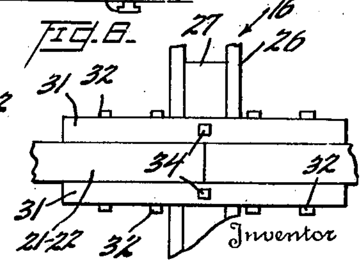


FIG. 7.

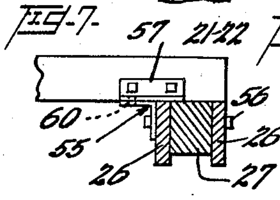
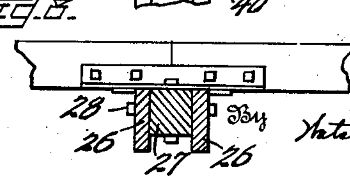


FIG. 8.



Inventor

Charles Mackintosh

By Watson, Cole, Grindle & Watson

Attorney

BUILDING BRACE

Filed Sept. 25, 1942 3 Sheets-Sheet 2

FIG. 8.

Prior Art

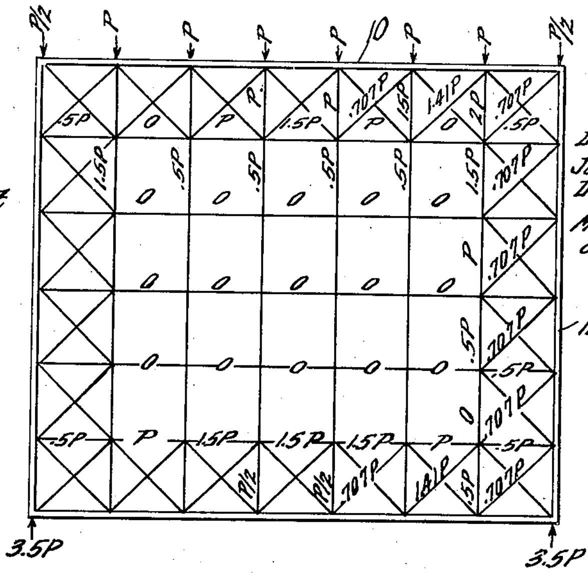


FIG. 10.

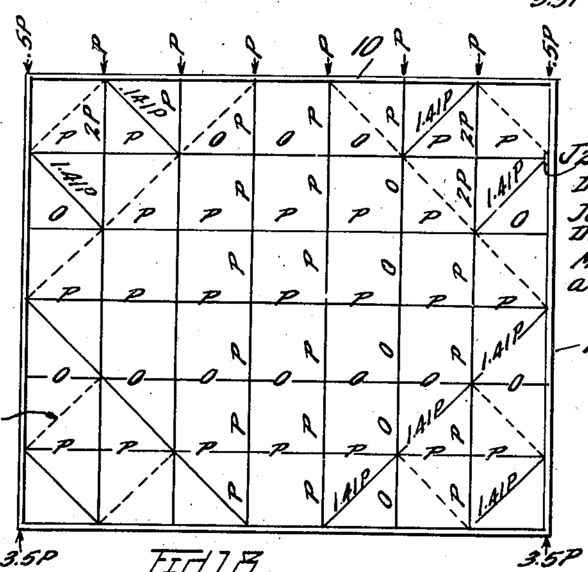
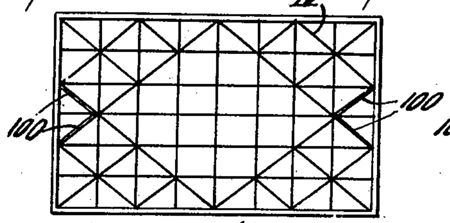
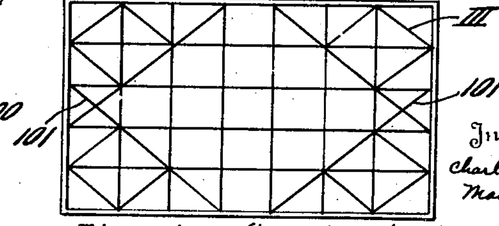


FIG. 17.



Diagonals-36 (instead of 48)
Joints with Diagonals-28 (instead of 48)

FIG. 18.



Diagonals-24 (instead of 40)
Joints with Diagonals-24 (instead of 40)

Inventor
Charles Mackintosh

By Watson, Cole, Grindle & Watson Attorneys

Sept. 7, 1943.

C. MACKINTOSH

2,329,068

BUILDING BRACE

Filed Sept. 25, 1942

3 Sheets-Sheet 3

FIG. 11.

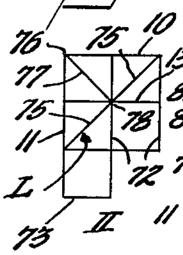


FIG. 12.

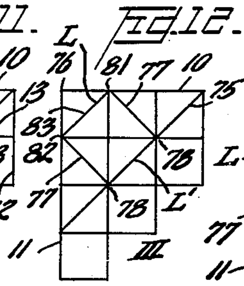


FIG. 13.

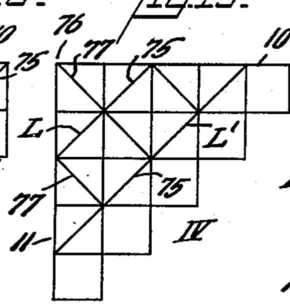


FIG. 14.

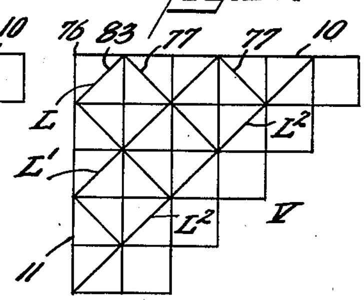


FIG. 18.

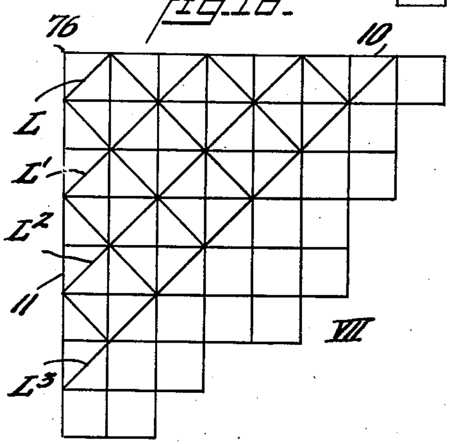


FIG. 15.

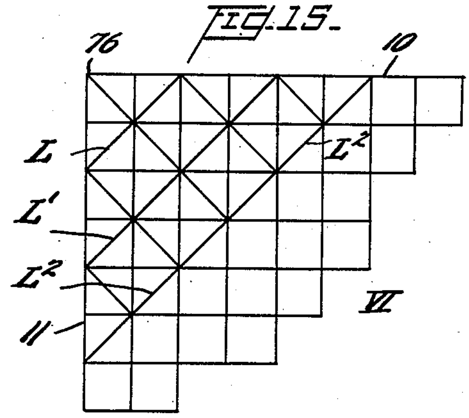
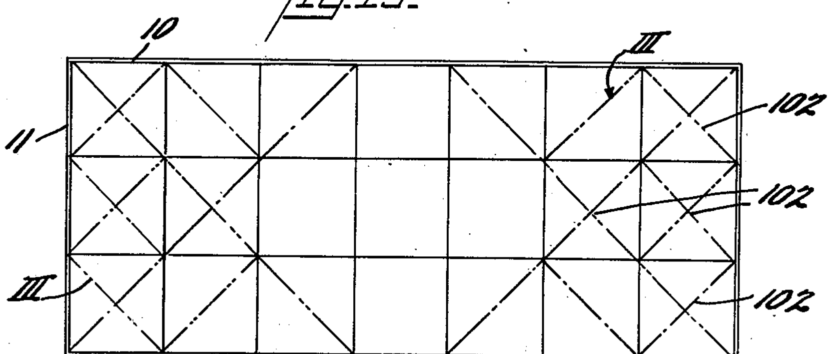


FIG. 19.



Diagonals-24 (instead of 36).
Joints with Diagonals-24 (instead of 36)

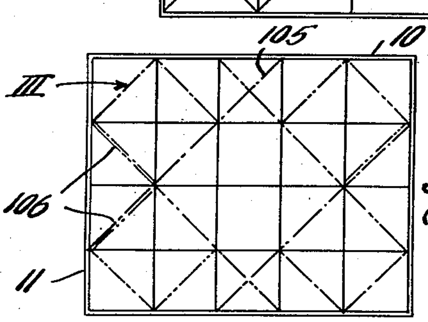


FIG. 20.

Diagonals-24 (instead of 28).
Joints with Diagonals-18 (instead of 28).

Inventor

Charles Mackintosh

By Watson, Cole, Grindle & Watson Attorney

Patented Sept. 7, 1943 2,329,068

UNITED STATES PATENT OFFICE

2,329,068

BUILDING BRACE

Charles Mackintosh, Los Angeles, Calif.

Application September 25, 1942, Serial No. 459,702

12 Claims. (Cl. 20—1)

The present invention relates to building constructions and more particularly to roof or floor bracing arrangements primarily intended to sustain the structure to which they are applied against lateral stresses whether due to wind, seismic disturbances, or any other cause.

The present invention has for its general object the provision of novel and improved bracing systems or grids which will be completely effective in rigidifying building structures of a wide variety of types whereby they may sustain all expected horizontal stresses with a minimum of outlay for labor and materials.

In its illustrated embodiments the invention is applied to one-story wooden structures having rather wide roof truss spans, such as commonly used in the construction of garages, shops, aircraft hangers, and the like, but it is obvious that the principles of the invention may be embodied in metallic or masonry structures, or in buildings with two or more stories, with equal effectiveness.

In the type of construction adopted for illustration and comparison, the framework of the building comprises a series of posts or columns dividing the side wall areas into bays. These columns serve to support the ends of arched roof trusses which extend across the building from side to side thereof, or if the structure is of considerable width, one or more lines of columns or posts may be disposed within the confines of the building area and in parallel relation to the side wall columns, and the adjacent inner ends of two or more aligned truss members may be supported on these interior columns.

The grid or bracing system is preferably disposed at the level of the lower chords of the trusses and comprises these lower chord elements themselves and a series of transversely extending struts intersecting and connected with the chords preferably at uniform intervals. This is common practice and it is also conventional to connect certain of the intersections between truss members and the transverse struts by means of diagonally extending rods, struts, braces or the like. Obviously, in the case of small buildings or buildings which are subdivided into a great number of rooms by wall partitions, such cross bracing is in most cases unnecessary, since these horizontal forces will be successfully resisted by the ordinary constructions; but in the cases of structures of large area, especially those employing roof trusses of any considerable span, such cross bracing is necessary to transmit the horizontal forces or their components from the wall to which they are perpendicular to the walls which extend in the same direction as those forces or components.

Most of the cross-bracing systems now in use for sustaining and transmitting such horizontal loads produce large stresses near the centers of the bracing trusses with corresponding unsatisfactory results and with high costs of manufacture and installation. In other systems which have been proposed to overcome these deficiencies, the loads or stresses must travel the full length or breadth of the building before encountering resisting elements. Also in conventional systems, the average number of diagonals attached to one joint between the truss members and the struts is about one-half that occurring in the present system, making it necessary to have a great many more joints provided with means for attachment of such diagonals. While it is true that the costs of the individual joint structures are about the same whether one or four diagonals are attached thereto, a considerable saving is possible in the use of joints where no provision for the attachment of diagonals is necessary.

Therefore, more particular objects of the invention are: to reduce to a minimum the total number of connections at intersections of longitudinal and transverse members which must have provisions for diagonal members; to reduce to a minimum the stress of any longitudinal or transverse member when the structure is under load; to provide a system of less deflection than heretofore possible using equal numbers and sizes of members and connections. In general the force in any longitudinal or transverse member need not be greater than the component of force from the diagonal member under maximum load which is attached along such longitudinal or transverse member, except that such force may equal the external panel point load.

A still further object of the invention is to provide bracing systems which not only resist the expected uniform loads caused by winds, earthquake or other forces efficiently and with great economy, but which also will satisfactorily resist large unbalanced loads and horizontal forces arising from these causes.

Other objects and features of novelty will be apparent from the following specification when read in connection with the accompanying drawings in which certain embodiments of the invention are illustrated by way of example.

In the drawings:

Figure 1 is a somewhat diagrammatic view in horizontal section of a building structure embodying the principles of the invention, the section being taken at approximately the level of the lower chords of the roof trusses of the building;

Figure 2 is a diagrammatic view in side elevation of the structure;

Figure 3 is a similarly diagrammatic view in end elevation of the building.

Figures 4, 5, and 6 are fragmentary plan views of three different types of joints between the various elements of the bracing grid of the building;

Figures 7 and 8 are views in vertical section of the joints shown in Figures 4 and 5 respectively and taken on the line 7—7 and 8—8 of those figures;

Figure 9 is a diagrammatic horizontal sectional view similar to Figure 1 but showing a bracing arrangement typical of the prior art;

Figure 10 is a similar view showing a novel bracing arrangement embodying the principles of the present invention;

Figure 11 is a diagrammatic fragmentary view in plan of an elemental corner bracing which occurs in several of the embodiments of the present invention; this elemental pattern being designated for the sake of convenience as type II;

Figure 12 shows another elemental corner arrangement which will be referred to as type III;

Figures 13, 14, 15, and 16 are amplifications of the elemental corner arrangements shown in Figures 11 and 12, these enlarged bracing areas being for use in buildings of increased size; and

Figures 17, 18, 19, and 20 are diagrams of horizontal sections of buildings of various proportions and subdivisions, with differing bracing patterns applied thereto, said patterns having differing degrees of overlapping.

The arrangement shown in Figures 1 to 3 of the drawings comprises a special form of invention designed to transmit the horizontal forces imposed upon one wall of the structure, by wind, seismic disturbances, explosive forces, or the like, to the other wall of the building. In this example the building is a one-story structure having a roof supported by trusses of considerable length, and the horizontal bracing grid or network is arranged at the approximate level of the lower chords of the roof supporting trusses, as is conventional in this type of building. Such buildings find wide practical use as garages, shops, aircraft hangers, etc. However, the principles of the invention and the specific embodiment of cross bracing illustrated diagrammatically herein, are suitable for use in interior bracing arrangements for any type of building regardless of the height or materials of construction employed.

In this first specific example of the invention, the side walls of the building are designated by the reference numeral 10 and the end walls by the numeral 11. The side walls 10 of the building including the posts or columns 12 which are arranged at suitable intervals along the wall as indicated in Figure 2 of the drawings. Certain of these posts 12 may be cross braced by means of the tie rods 13 as indicated. Since, in this example, the building is of considerable width, two aligned roof trusses are employed to span the width of the structure and an intermediate line of posts 14 must be used to support the abutting inner ends of the trusses. These roof-supporting trusses may be of any desired type, but the ones shown at 15 in the drawings are arch trusses with straight horizontal lower chords 16. A suitable form of truss bracing is indicated at 17. All the posts or columns 12 and 14 are set upon suitable footings 18 forming the foundation for the building.

The outer ends of the parallel trusses are rigidly braced and connected by means of the struts 20 and the inner abutting ends of the trusses are similarly connected by means of the struts 21. Other bracing struts 22 are disposed at intermediate points and are rigidly connected between the lower chords 16 of the spaced truss members. These rectilinear truss chords and struts form a grid or network extending throughout the entire area of the structure and divide this area into a plurality of rectangular spaces.

In most of the prior constructions of this type all of these rectangular spaces along the margin of the building structure were provided with intersecting diagonal tension sustaining braces as indicated in Figure 9 of the drawings. However, I have found that, by following the principles of the present invention as set forth herein, considerable savings in material used in constructing the joint connections may be effected. For example, in the specific example shown in Figure 1 of the drawings, diagonal bracing members 25 are employed to connect certain of the joints between the lower chord members 16 of the trusses and the connecting struts 20, 21, and 22. These bracing elements, in this specific example, comprise rods which are adapted to be secured at their ends to the joint structures by means of clevises or the like. It will be seen that at some of the joints there will be no diagonal rods for connection thereto; at others of the joints there will be one, two, three, or four rod end connections. Furthermore, at the marginal joints there will be only one strut abutting a truss chord, while in others there will be two struts each connecting the chord with the chord of an adjacent truss. Suggestive and non-limiting detailed examples of these joints are illustrated in Figures 4–8 of the drawings. The joints shown in Figures 5, 6, and 8 are especially adapted to the structure shown in Figures 1, 2, and 3 of the drawings, the arrangement shown in Figure 6 being suitable for joints at which no diagonals occur, such as indicated at J_1 in Figure 1. The joint shown in Figures 5 and 8 includes provision for the connection of from one to four diagonals and is suitable for use at the positions indicated at J_3 and J_4 in Figure 1.

In these detailed views the lower chord members 16 of the struts are shown as being comprised of two spaced timbers 26 between which a spacing element 27 is disposed. The spaced elements 26 are secured together as by means of the bolts 28 and the aligned abutting struts 21 or 22 extend above the chord member 16 as shown in Figure 8. In the joints of the type J_1, where there are no diagonal brace rods to be connected, the abutting ends of the struts 21, 22 may be secured together between the wooden plates 31, bolts 32 being employed to secure the plates and struts together. The plates 31 are rigidly connected with the spacing members 27 of the chords 16 by means of the vertically disposed bolts 34.

In Figures 5 and 8, the joints J_3 and J_4 are illustrated and in these cases the plates 31 are omitted and metal angle plates 40 are employed, the vertical flanges 41 of these plates embracing the abutting ends of the struts 21, 22 and being secured thereto by means of the bolts 42. The horizontal flanges 45 of the plates 40 are secured to the parts 27 of the chord 16 by means of the vertical bolts 44. The horizontal flanges 45 are also provided with holes 48 through which clevises 50 may be inserted for connecting the diagonal braces 25 at their respective ends. As many openings 48 are provided in the flanges of the angle plates as are required for the diagonal connections in the joints.

The arrangement shown in Figures 4 and 7 of the drawings is not employed in the embodiment illustrated in Figures 1 to 3, but this type of connection would be made between the truss chord at one of the end walls of the structure and an abutting strut 21 or 22. Such a junction could be employed, for example, at the joint designated J_2 in Figure 10 of the drawings. In this case the lower chord 16 of the end truss comprises the usual elements 26 and 27 and the strut 21, 22 is disposed with its end resting upon the chord 16, or if there is no end truss a similar connection could be made with the wall plate instead of a truss chord. In order to rigidify the joint and to provide means for the attachment of the diagonal bracing elements an angle plate 55 has its vertical flange secured against the chord 16 by means of the bolt 56. The horizontal upper flange of the angle piece 55 is disposed beneath the strut 21, 22 with its ends projecting laterally therefrom. Other angle pieces 57 are applied to the sides of the strut 21, 22 and are secured together through the struts by means of bolts 58. The horizontal flanges of these angle pieces 58 overlap portions of the horizontal flanges of the angle piece 55 and aligned openings 60 are made in the overlapped portions of these flanges, for the accommodations of the clevises 50 to which the diagonal brace rods 25 are connected.

Of course, in the broader aspects of the present invention, the joints between the trusses and the struts, and the application of the diagonal braces thereto, may be effected by any other suitable means, the specific arrangements shown and described herein being chiefly for the purpose of exemplifying an efficacious type of joint and also as indicating the saving effected in the construction of the joints where no diagonals are attached. At present prices, the saving in connection costs at each joint where all diagonal members are eliminated is from \$2.50 to \$5.00. This saving is in addition to the savings incidental to the elimination of the diagonal bracing elements themselves.

Now, in order to illustrate the effectiveness of the novel bracing arrangement and make a comparison with the common bracing expedients of the prior art, reference will be made to Figures 9 and 10 of the drawings taken in connection with certain diagrams forming parts of Figures 2 and 3. Assuming a wind pressure against one of the side walls 10 of a rectangular building of the general arrangements shown in these figures, it will be seen that the pressure against the wall surfacing which is secured to the wall studding, tends to bend the studding which acts as a beam extending between the floor and ceiling lines. Therefore, half of the pressure on the wall goes directly to the floor line and half goes upward to the ceiling or truss line. However, all of the wind which blows on the structure above the ceiling or truss level must be carried at this level. This is shown graphically in Figures 2 and 3 in which the height of the wall from the ground to the lower truss chord is h and the height of the truss itself is r. The width of the bay between columns 12 and the trusses 15 is w. Thus the magnitude of the wind force is expressed in the pounds per square foot of the wind pressure, multiplied by one-half the story height plus the height from the ceiling to the top of the truss, multiplied by the width of the portion of the wall backed up by the truss in question. This area is indicated by the shaded rectangle in Figure 2 and is equal to

$$w\left(\frac{h}{2}+r\right)$$

If the lateral pressure or force in lbs. per square foot is f, then the pressure p sustained by the end of one of the truss members, as indicated in Figures 1, 9, and 10 of the drawings will be

$$fw\left(\frac{h}{2}+r\right)$$

and these forces will be applied as indicated in the drawings. In the case of Figure 1 where there are 8 bays in the side walls of the building and 9 lines of members perpendicular to these walls, the force in shear delivered from the bracing system to each end wall to sustain the total force supplied to the side wall will be $4p$; while in the examples shown in Figures 9 and 10 the force in shear in each end wall will be $3.5p$.

In order to make the explanation more realistic, it may be assumed that the ceiling height of the building is 20 ft. and the height of the arch truss roof is 9 ft. Then, if the spacing of the trusses is 18 ft. and the wind pressure 15 lbs. per sq. ft., the value of p is $15\times18\times(10+9)=5130$ lbs.

By referring to the diagram illustrating the prior art in Figure 9, it will be seen that, assuming the wind pressure to be against the side wall 10 at the upper portion of the figure, the values for the stress set up in each of the struts, truss chord section, and diagonal bracing elements are as indicated in the drawings. Similarly, in Figure 10, with the wind pressure upon the side wall at the upper part of the figure, the various stresses set up in the truss struts and diagonal braces is also indicated. In Figure 10, it will be noted that the diagonal elements which are active in sustaining the stresses under the stated conditions are indicated in solid lines, while those which are idle under the stated wind conditions are shown in dotted lines. Obviously, if the wind direction were opposite, these indications would be reversed, and it will be clearly understood that in cases where the wind is moving endwise of the building the stresses would be similarly and symmetrically distributed. Of course, when the wind blows at an angle to the walls of the building the stresses will be distributed and calculated in accordance with the perpendicular components of the forces applied.

The following tabulation will very clearly show the savings of material and the better distribution of stresses in the embodiment of the present invention illustrated in Figure 10 as compared with the conventional arrangement of Figure 9:

	Figure 9	Figure 10
Maximum force in any one strut	1.5P	P
Maximum force in any one diagonal	1.41P	1.41P
Number of joints with diagonals attached	44	22
Number of diagonal brace rods	44	24

It will be seen that although the maximum force in any diagonal rod is the same in either case, the maximum force in a transverse strut is one and one-half times the value of P so that the connections in the old type of construction must be half again as strong as in the present system. Not only is this true, but in accordance with the present invention there are only half as many steel angle connected joints to be provided for the attachment of the diagonal braces. Furthermore, there are but slightly over half the number of diagonal brace rods necessary and yet the largest rod is no larger than the largest necessary to take the maximum stress in the old type of construction The earthquake or seismic force to be allowed for is commonly calculated quite similarly except that it is based upon the weight of the structure; for example, generally in structures of this type, this seismic force is assumed to be 8% of the weight of the structure at about the center of the first story plus an additional 8% of one half of the live load on the trusses.

It will be seen that basically the present invention involves the provision of triangular braced areas within the cross section of the building whereby, in effect, triangular horizontal truss sections are provided for transmitting the stresses directly sustained by a wall of the building to other walls of the building, either the one opposite the directly affected wall or the two end walls which are perpendicular to the wall against which the force is applied. In the case of the embodiment shown in Figure 1, the triangular bracing areas are disposed centrally of the building and the force is transmitted from one wall to another of the walls, other expedients such as knee braced trusses or the like being used, if necessary, to sustain pressures applied endwise of the building.

In the embodiment shown in Figure 10, the triangular braced areas serve to transmit the stress sustained by the side wall to the end walls of the building. In this arrangement, a line of diagonal braces extends from approximately the mid-points of the adjacent side and end walls, and the arrangements at the corners of the building are subdivided by means of other diagonal braces, while the substantially lozenged-shaped area in the center of the building is free of diagonal braces. Furthermore, it will be noted that in this specific arrangement, there are no crossed diagonals within any one rectangular space into which the area of the structure is divided.

However, these particular conditions hold good only in cases where the corner patterns do not lap each other as they do in certain of the other illustrated embodiments.

In Figures 11 and 12 of the drawings there are illustrated certain basic patterns of corner bracing which comprise one of the essential features of the present invention.

In Figure 11 one wall of the building indicated at 10 intersects with an adjacent wall 11 at right angles. The parallel transverse elements comprising either trusses or struts, which abut the wall 10 and the opposite wall (not shown), are indicated at 72. The opposite extending parallel elements which abut the wall 11 and the other opposite wall are designated by the reference numeral 73. In this arrangement the aligned diagonal bracing elements 75 form a line L which bounds the triangular bracing area at the building corner in this embodiment. It will be noted that the line L connects points on the walls 10 and 11 each of which are spaced from the corner point 76 by the width of two bays. The corner network in this instance is completed by the diagonal element 77 which connects the wall area corner point 76 with the juncture 78 between the two braces 75. It will be seen that the bracing elements and the walls or boundaries of the building area in this example are divided into two equilateral triangles, the bases of which form portions of the walls or boundaries and certain sides of which comprise the bounding line L of the triangular bracing network area.

In Figure 12 of the drawings another elemental form of corner bracing is shown. In this case the walls 10 and 11 are intersected by the bounding line of braces L^1 at points spaced by the width of three bays from the corner 76. In this case there are two diagonal bracing elements 77 which extend from two joints 78 between the braces 75 to the points 81 and 82 which are spaced from the corner 76 by the width of one bay along each wall. These points are joined by another diagonal 83, which completes the corner network. This diagonal may also be designated L since it is the first oblique line from the corner 76 which intersects the walls 10 and 11. It will be seen that the network formed by the diagonals, comprises one complete equilateral parallelogram flanked by two equilateral triangles adjacent the walls of boundaries 10 and 11 and a small triangle at the far corner of the arrangement which triangle is bounded by the points 76, 81, and 82 and is equal to one quarter of the area of the equilateral parallelogram.

In Figure 13 there is shown an amplification of the elemental arrangement illustrated in Figure 11. Another bounding line L^1 is formed parallel with the line L and forms a new boundary for the triangular area extending from a point four bays from the corner 76 on the wall 10 to a point on the wall 11 which is also four bays from the corner 76. The connecting diagonals 77 are added, thus completing the corner network which in this case comprises two equilateral parallelograms flanked by equilateral triangles and topped by a pair of equilateral triangles similar to the entire network of Figure 11.

In Figure 14 the arrangement of Figure 12 is amplified by the addition of a further line L^2 composed of five aligned diagonals and connecting points on the walls 10 and 11 which are respectively spaced from the corner 76 by the width of five bays on either wall.

Figures 15 and 16 show diagrammatically the extension of the elemental arrangement of Figure 11 to cover six bays along each wall and the arrangement in Figure 12 to cover seven bays along each wall, respectively.

For convenience of reference the elemental arrangement of Figure 11 will be designated type II, the arrangement of Figure 12 will be referred to as type III; and the amplified networks shown in Figures 13, 14, 15, and 16 will be referred to as types IV, V, VI, and VII, respectively.

Obviously, buildings to which the invention may be applied are subdivided into differing numbers of rectangular areas, and their walls into differing numbers of bays, and the exact arrangement of bracings of whatever type selected may vary to some extent in each case. Also, the triangular bracing networks may be disposed symmetrically in the same relationship with respect to certain intermediate lines through a building, as with respect to the outer walls of the building; for example, as already shown and described in connection with Figure 1 of the drawings, in which the pattern III is used to brace the respective halves of walls 10 as referred to the center line C.L. of the building.

The triangular areas at adjacent corners of a building area may be spaced from each other at the center of the wall or boundary line, may abut each other at that point, or may overlap either by the width of one bay or by the entire extent of the wall. As will be understood from further descriptions and illustrations, this may result in the occurrence of crossed diagonals within one or more of the rectangular areas formed by the trusses or struts, or it may result in the superposing of bracing elements along certain diagonals where the bracing patterns overlap.

In Figure 10 of the drawings, the building has seven bays along the side wall and six along the ends. Type III bracing is used, the patterns being spaced by the width of one bay on one side and being contiguous at the ends.

In Figure 11 of the drawings, where there are eight bays along the side walls and six along the end walls, the arrangement will be as illustrated, wherein the corner pattern designated type IV is employed, the lines of diagonals which bound the triangular bracing areas meet at a single point at the center of the longer walls, but these areas overlap by the width of two bays on the end walls. This causes certain of the diagonals of these overlapping patterns to be superposed as shown at 100 in Figure 11.

In Figure 12 where there are seven bays along the side walls and only five along the end walls and type III bracing pattern is used, the points of connection of the bounding line of diagonals with the side walls are spaced apart by the width of one bay as in the case of Figure 10, and the corner patterns overlap on the end walls by the width of one bay, forming the crossed diagonal patterns indicated at 101 in these bays.

In Figure 19 of the drawings, a long narrow building is shown having seven bays along the side walls and only three bays along the end walls. The type III design of corner bracing is used, and it will be seen that the patterns are spaced along the side walls by the width of one bay, but that they overlap completely along the end walls, that is, by the width of the three bays comprising said walls. This causes crossed patterns of bracing to occur in four of the triangular areas as indicated at 102 in Figure 19. In this figure and also in Figure 20, the adjacent overlapping triangular patterns are indicated by different chain lines so that they may be more readily distinguished.

In Figure 20 there is illustrated a horizontal plan of a building which is nearly square having five bays along the side walls and four bays along the end walls. Type III bracing pattern is employed and it will be seen that the corner networks overlap along the side walls by the width of one bay, yielding crossed diagonals as indicated at 105, and they overlap by the width of two bays at the end walls, making superposed diagonal braces necessary as indicated at 106.

The various adjustments of the basic designs are peculiar to the variations in the horizontal sections of the buildings and the truss and strut distributions, but they do not depart substantially from the fundamental arrangements illustrated and described herein in connection particularly with Figure 10 of the drawings, and the savings in diagonal braces and the metallic joints for the diagonals are substantial. In the case of the arrangement shown in Figure 17 of the drawings 36 diagonals are used instead of 48 and there are only 28 joints with diagonals attached instead of 48, as would be the case of the corresponding prior art arrangements in a building of six by eight panels or bays. In the case of the arrangement shown in Figure 18, the number of diagonals is reduced from 40 to 24 and the number of joints with diagonals from 40 to 24 as compared with the prior art arrangements. In Figure 19, the number of diagonals is reduced from 36 to 24 as compared with the corresponding prior art arrangement, and joints with diagonals are also reduced in number from 36 to 24. Similarly the number of diagonals employed in the arrangement shown in Figure 20 is reduced from 28 to 24 and the joints with diagonals reduced from 28 to 18 as compared with the equivalent prior art structure.

It will be seen that by means of the present invention, there has been provided a novel horizontal bracing arrangement by which more effective support of a building against lateral applied forces may be attained with a considerably less outlay for materials and labor than in the case of conventional constructions.

At the same time, the novel arrangement results in less concentration of stress in the individual members, which means that there is less elastic deformation and less joint slip. More uniform standardized sizes of material is made possible and therefore a greater duplication of details in the case of all members of the structure.

It is understood that various changes and modifications may be made in the embodiment illustrated and described herein without departing from the scope of the invention as defined by the following claims.

Having thus described the invention, what I claim as new and desire to secure by Letters Patent is:

1. In a rectangular building structure having one or more walls subject to horizontal forces, a bracing system for transmitting such forces to othher walls of the structure, said system comprising a series of substantially parallel horizontal members extending from one wall to the opposite wall and dividing said walls into a plurality of bays of approximately equal width, a series of other substantially parallel horizontal members extending at right angles to the members of the first named series, connecting the other two opposed walls, and dividing them into a plurality of bays of approximately equal width, said series of members also dividing the horizontal sectional area of the structure into a plurality of rectangular spaces, means forming joints connecting the members of said first series with those of the second series, and both of said series with the walls of the building, at their several points of intersection, and elements for sustaining tension stresses only extending diagonally across certain of said rectangular spaces and connnecting certain of said joints at diagonally opposite corners of said spaces, a line of said diagonal tension elements extending from a point along one wall which is spaced from the corner of said building area by the width of two or more bays to a point on the adjacent wall spaced at the same number of bays from the corner, said line of diagonal tension elements defining with said adjacent walls a triangular bracing area, said area comprising a network of said diagonal elements which includes said limiting line of diagonal elements and one or more additional diagonal elements connected as described at the junction of the individual diagonal elements of said line, the aforesaid network comprising the only ones of such diagonal tension elements employed at said corner.

2. In a rectangular building structure having one or more walls subject to horizontal forces, a

bracing system for transmitting such forces to other walls of the structure, said system comprising a series of substantially parallel horizontal members extending from one wall to the opposite wall and dividing said walls into a plurality of bays of approximately equal width, a series of other substantially parallel horizontal members extending at right angles to the members of the first named series, connecting the other two opposed walls, and dividing them into a plurality of bays of approximately equal with, said series of members also dividing the horizontal sectional area of the structure into a plurality of rectangular spaces, means forming joints connecting the members of said first series with those of the second series, and both of said series with the walls of the building, at their several points of intersection, and elements for sustaining tension stresses only extending diagonally across certain of said rectangular spaces and connecting certain of said joints at diagonally opposite corners of said spaces, a line of said diagonal tension elements extending from a point along one wall which is spaced from the corner of said building area by the width of three or more bays to a point on the adjacent wall spaced at the same number of bays from the corner, said line of diagonal tension elements defining with said adjacent walls a triangular bracing area, said area comprising a network of said diagonal elements which includes said limiting line of diagonal elements and one or more additional diagonal elements connected as described at the junction of the individual diagonal elements of said line.

3. In a rectangular building structure having one or more walls subject to horizontal forces, a bracing system for transmitting such forces to other walls of the structure, said system comprising a series of substantially parallel horizontal members extending from one wall to the opposite wall and dividing said walls into a plurality of bays of approximately equal width, a series of other substantially parallel horizontal members extending at right angles to the members of the first named series, connecting the other two opposed walls, and dividing them into a plurality of bays of approximately equal width, said series of members also dividing the horizontal sectional area of the structure into a plurality of rectangular spaces, means forming joints connecting the members of said first series with those of the second series, and both of said series with the walls of the building, at their several points of intersection, and elements for sustaining tension stresses only extending diagonally across certain of said rectangular spaces and connecting certain of said joints at diagonally opposite corners of said spaces, a plurality of parallel oblique lines of said diagonal tension elements extending respectively from points along one wall spaced from the corner of said building area by the width of one or more bays to corresponding points on the adjacent wall spaced from the corner by the same number of bays, the successive points of intersection of said walls and lines being spaced apart along said walls by the width of two bays, said lines of diagonal tension elements defining with said adjacent walls a triangular bracing area, said area comprising a network of said diagonal elements which includes said limiting lines of diagonal elements and additional diagonal elements connected as described at the junction of the individual diagonal elements of said lines.

4. In a rectangular building structure having one or more walls subject to horizontal forces, a bracing system for transmitting such forces to other walls of the structure, said system comprising a series of substantially parallel horizontal members extending from one wall to the opposite wall and dividing said walls into a plurality of bays of approximately equal width, a series of other substantially parallel horizontal members extending at right angles to the members of the first named series, connecting the other two opposed walls, and dividing them into a plurality of bays of approximately equal width, said series of members also dividing the horizontal sectional area of the structure into a plurality of rectangular spaces, means forming joints connecting the members of said first series with those of the second series, and both of said series with the walls of the building, at their several points of intersection, and elements for sustaining tension stresses only extending diagonally across certain of said rectangular spaces and connecting certain of said joints at diagonally opposite corners of said spaces, said diagonal elements forming triangular bracing areas extending from each corner of the building area along the adjacent sides, and each bracing area including a line of said diagonal tension elements extending from a point along one wall which is spaced from the corner of said building area by the width of two or more bays to a point on the adjacent wall spaced at the same number of bays from the corner, said area comprising a network of said diagonal elements which includes said limiting line of diagonal elements and one or more additional diagonal elements connected as described at the junction of the individual diagonal elements of said line, the aforesaid network comprising the only ones of such diagonal tension elements employed at said corner.

5. In a rectangular building structure having one or more walls subject to horizontal forces, a bracing system for transmitting such forces to other walls of the structure, said system comprising a series of substantially parallel horizontal members extending from one wall to the opposite wall and dividing said walls into a plurality of bays of approximately equal width, a series of other substantially parallel horizontal members extending at right angles to the members of the first named series, connecting the other two opposed walls, and dividing them into a plurality of bays of approximately equal width, said series of members also dividing the horizontal sectional areas of the structure into a plurality of rectangular spaces, means forming joints connecting the members of said first series with those of the second series, and both of said series with the walls of the building, at their several points of intersection, and elements for sustaining tension stresses only extending diagonally across certain of said rectangular spaces and connecting certain of said joints at diagonally opposite corners of said spaces, said diagonal elements forming triangular bracing areas extending from each corner of the building area along the adjacent sides, and each tension area including a plurality of parallel oblique lines of said diagonal bracing elements extending respectively from points along one wall spaced from the corner of said building area by the width of one or more bays to corresponding points on the adjacent wall spaced from the corner by the same number of bays, the successive points of intersection of said walls and lines being spaced apart along said walls by the width of two bays, said area comprising a net-

work of said diagonal elements which includes said limiting lines of diagonal elements and additional diagonal elements connected as described at the junction of the individual diagonal elements of said lines.

6. In a rectangular building structure having one or more walls subject to horizontal forces, a bracing system for transmitting such forces to other walls of the structure, said system comprising a series of substantially parallel horizontal members extending from one wall to the opposite wall and dividing said walls into a plurality of bays of approximately equal width, a series of other substantially parallel horizontal members extending at right angles to the members of the first named series, connecting the other two opposed walls, and dividing them into a plurality of bays of approximately equal width, said series of members also dividing the horizontal sectional area of the structure into a plurality of rectangular spaces, means forming joints connecting the members of said first series with those of the second series, and both of said series with the walls of the building, at their several points of intersection, and elements for sustaining tension stresses only extending diagonally across certain of said rectangular spaces and connecting certain of said joints at diagonally opposite corners of said spaces, said diagonal elements forming triangular bracing areas extending from each corner of the building area along the adjacent sides, and each bracing area including a line of said diagonal tension elements extending from a point along one wall which is spaced from the corner of said building area by the width of two or more bays to a point on the adjacent wall spaced at the same number of bays from the corner, said area comprising a network of said diagonal elements which includes said limiting line of diagonal elements and one or more additional diagonal elements connected as described at the junction of the individual diagonal elements of said line, the aforesaid network comprising the only ones of such diagonal tension elements employed at said corner, certain of the sides of said triangular areas which coincide with the sides of said building area being of a length equal to more than one-half of the length of said corresponding building sides, whereby said triangular areas overlap at certain of their adjacent apexes.

7. In a rectangular building structure having one or more walls subject to horizontal forces, a bracing system for transmitting such forces to other walls of the structure, said system comprising a series of substantially parallel horizontal members extending from one wall to the opposite wall and dividing said walls into a plurality of bays of approximately equal width, a series of other substantially parallel horizontal members extending at right angles to the members of the first named series, connecting the other two opposed walls, and dividing them into a plurality of bays of approximately equal width, said series of members also dividing the horizontal sectional area of the structure into a plurality of rectangular spaces, means forming joints connecting the members of said first series with those of the second series, and both of said series with the walls of the building, at their several points of intersection, and elements for sustaining tension stresses only extending diagonally across certain of said rectangular spaces and connecting certain of said joints at diagonally opposite corners of said spaces, said diagonal elements forming triangular bracing areas extending from each corner of the building area along the adjacent sides, and each bracing area including a plurality of parallel oblique lines of said diagonal tension elements extending respectively from points along one wall spaced from the corner of said building area by the width of one or more bays to corresponding points on the adjacent wall spaced from the corner by the same number of bays, the successive points of intersection of said walls and lines being spaced apart along said walls by the width of two bays, said area comprising a network of said diagonal elements which includes said limiting lines of diagonal elements and additional diagonal elements connected as described at the junction of the individual diagonal elements of said lines, certain of the sides of said triangular areas which coincide with the sides of said building area being of a length equal to more than one-half of the length of said corresponding building sides, whereby said triangular areas overlap certain of their adjacent apexes.

8. In a rectangular building structure having one or more walls subject to horizontal forces, a bracing system for transmitting such forces to other walls of the structure, said system comprising a series of substantially parallel horizontal members extending from one wall to the opposite wall and dividing said walls into a plurality of bays of approximately equal width, a series of other substantially parallel horizontal members extending at right angles to the members of the first named series, connecting the other two opposed walls, and dividing them into a plurality of bays of approximately equal width, said series of members also dividing the horizontal sectional area of the structure into a plurality of rectangular spaces, means forming joints connecting the members of said first series with those of the second series, and both of said series with the walls of the building, at their several points of intersection, and elements for sustaining tension stresses only extending diagonally across certain of said rectangular spaces and connecting certain of said joints at diagonally opposite corners of said spaces, a line of said diagonal tension elements extending from a point along one wall which is spaced from the corner of said building area by the width of three or more bays to a point on the adjacent wall spaced at the same number of bays from the corner, said line of diagonal bracing elements defining with said adjacent walls a triangular bracing area, said area comprising a network of said diagonal elements which includes said limiting line of diagonal elements and one or more additional diagonal elements connected as described at the junction of the individual diagonal elements of said line, the diagonal tension elements forming with themselves equal equilateral parallelograms and forming with the walls of said building areas triangles which are aliquot parts of said parallelograms.

9. In a rectangular building structure having one or more walls subject to horizontal forces, a bracing system for transmitting such forces to other walls of the structure, said system comprising a series of substantially parallel horizontal members extending from one wall to the opposite wall and dividing said walls into a plurality of bays of approximately equal width, a series of other substantially parallel horizontal members extending at right angles to the members of the first named series, connecting the other two opposed walls, and dividing them into a plurality of bays of approximately equal width, said series of members also dividing the horizontal

sectional area of the structure into a plurality of rectangular spaces, means forming joints connecting the members of said first series with those of the second series, and both of said series with the walls of the building, at their several points of intersection, and elements for sustaining tension stresses only extending diagonally across certain of said rectangular spaces and connecting certain of said joints at diagonally opposite corners of said spaces, said diagonal elements forming triangular bracing areas extending from each corner of the building area along the adjacent sides, and each bracing area including a plurality of parallel oblique lines of said diagonal tension elements extending respectively from points along one wall spaced from the corner of said building area by the width of one or more bays to corresponding points on the adjacent wall spaced from the corner by the same number of bays, the successive points of intersection of said walls and lines being spaced apart along said walls by the width of two bays, said area comprising a network of said diagonal elements which includes said limiting lines of diagonal elements and additional diagonal elements connected as described at the junction of the individual diagonal elements of said lines, the diagonal tension elements forming with themselves equal equilateral parallelograms and forming with the walls of said building areas triangles which are aliquot parts of said parallelograms.

10. In a rectangular building structure having one or more walls subject to horizontal forces, a bracing system for transmitting such forces to other walls of the structure, said system comprising a series of substantially parallel horizontal members extending from one wall to the opposite wall and dividing said walls into a plurality of bays of approximately equal width, a series of other substantially parallel horizontal members extending at right angles to the members of the first named series, connecting the other two opposed walls, and dividing them into a plurality of bays of approximately equal width, said series of members also dividing the horizontal sectional area of the structure into a plurality of rectangular spaces, means forming joints connecting the members of said first series with those of the second series, and both of said series with the walls of the building, at their several points of intersection, and elements for sustaining tension stresses only extending diagonally across certain of said rectangular spaces and connecting certain of said joints at diagonally opposite corners of said spaces, said diagonal elements forming triangular bracing areas extending from each corner of the building area along the adjacent sides, and each bracing area including a plurality of parallel oblique lines of said diagonal tension elements extending respectively from points along one wall spaced from the corner of said building area by the width of one or more bays to corresponding points on the adjacent wall spaced from the corner by the same number of bays, the successive points of intersection of said walls and lines being spaced apart along said walls by the width of two bays, said area comprising a network of said diagonal elements which includes said limiting lines of diagonal elements and additional diagonal elements connected as described at the junction of the individual diagonal elements of said lines, certain of the sides of said triangular areas which coincide with the sides of said building area being of a length equal to more than one-half of the length of said corresponding building sides, whereby said triangular areas overlap certain of their adjacent apexes, the diagonal tension elements forming with themselves equal equi-lateral parallelograms and forming with the walls of said building areas triangles which are aliquot parts of said parallelograms, none of the said rectangular spaces containing crossed diagonal tension elements except in certain cases where said triangular bracing areas overlap.

11. In a rectangular building structure having one or more walls subject to horizontal forces, a bracing system for transmitting such forces to other walls of the structure, said system comprising a series of substantially parallel horizontal members extending from one wall to the opposite wall and dividing said walls into a plurality of bays of approximately equal width, a series of other substantially parallel horizontal members extending at right angles to the members of the first named series, connecting the other two opposed walls, and dividing them into a plurality of bays of approximately equal width, said series of members also dividing the horizontal sectional area of the structure into a plurality of rectangular spaces, means forming joints connecting the members of said first series with those of the second series, and both of said series with the walls of the building, at their several points of intersection, and elements for sustaining tension stresses only extending diagonally across certain of said rectangular spaces and connecting certain of said joints at diagonally opposite corners of said spaces, said diagonal tension elements forming triangular braced areas, comprising in effect horizontal triangular trusses, a wall subject to said horizontal forces substantially comprising the side of one of said triangular braced areas.

12. In a rectangular building structure having one or more walls subject to horizontal forces, a bracing system for transmitting such forces to other walls of the structure, said system comprising a series of subtantially parallel horizontal member extending from one wall to the opposite wall and dividing said walls into a plurality of bays of approximately equal width, a series of other substantially parallel horizontal members extending at right angles to the members of the first named series, connecting the other two opposed walls, and dividing them into a plurality of bays of approximately equal width, said series of members also dividing the horizontal sectional area of the structure into a plurality of rectangular spaces, means forming joints connecting the members of said first series with those of the second series, and both of said series with the walls of the building, at their several points of intersection, and elements for sustaining tension stresses only extending diagonally across certain of said rectangular spaces and connecting certain of said points at diagonally opposite corners of said spaces, said diagonal tension elements forming triangular braced areas, comprising in effect horizontal triangular trusses, a wall subject to said horizontal forces substantially comprising the side of one of said triangular truss areas, the other sides of said triangular areas being respectively comprised by the adjacent perpendicularly extending walls of the structure.

CHARLES MACKINTOSH.