July 31, 1945. J. LOEWENSTEIN 2,380,600

BUILDING CONSTRUCTION

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Fig. 1.

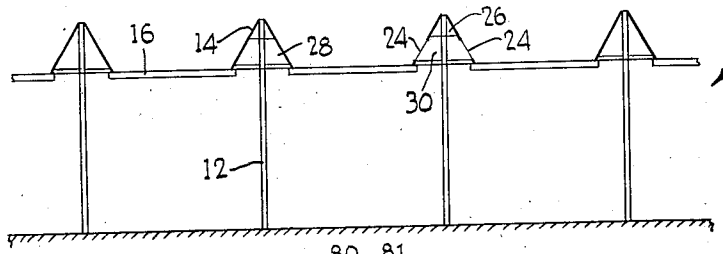


Fig. 2.

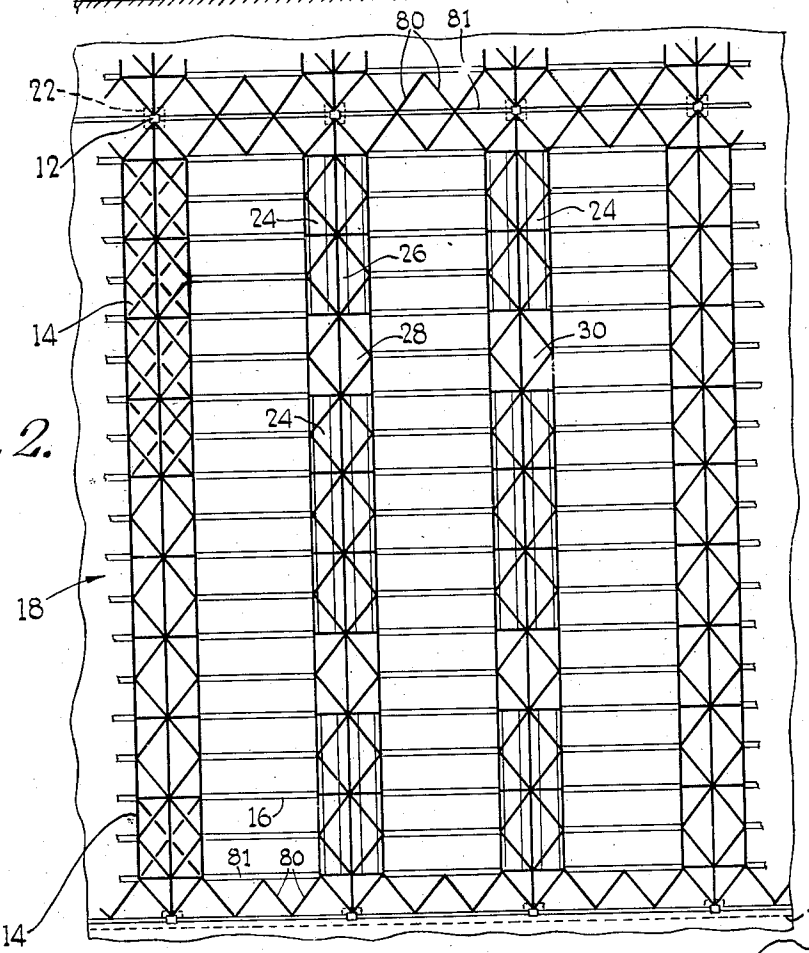
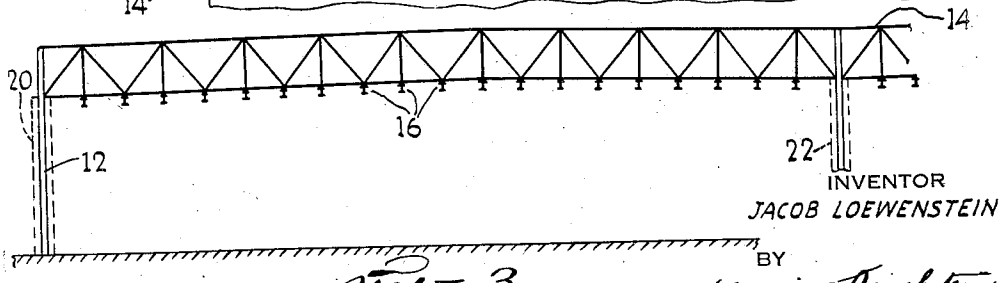


Fig. 3.



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BUILDING CONSTRUCTION

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Fig. 4.

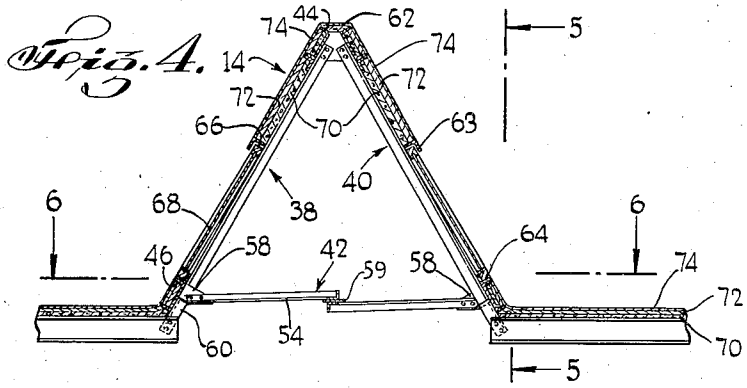


Fig. 5.

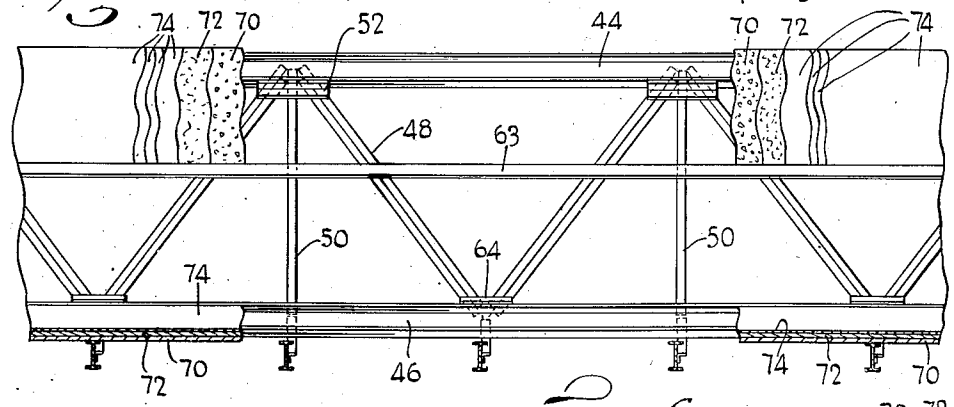


Fig. 6.

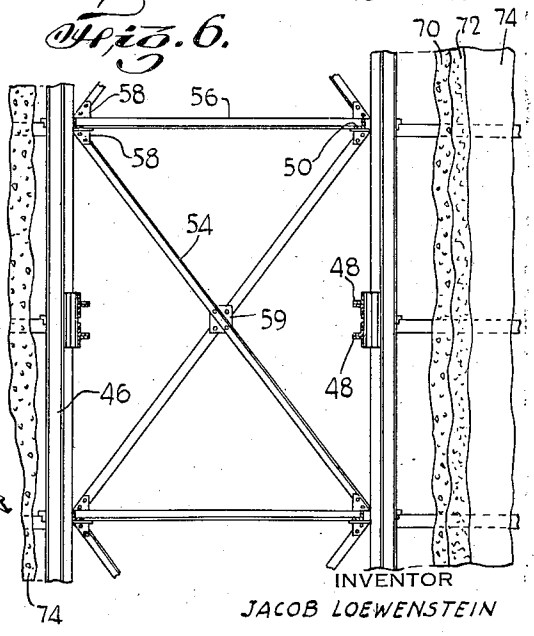
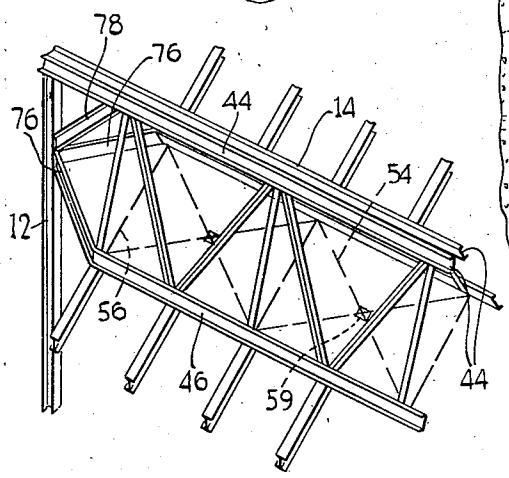


Fig. 7.



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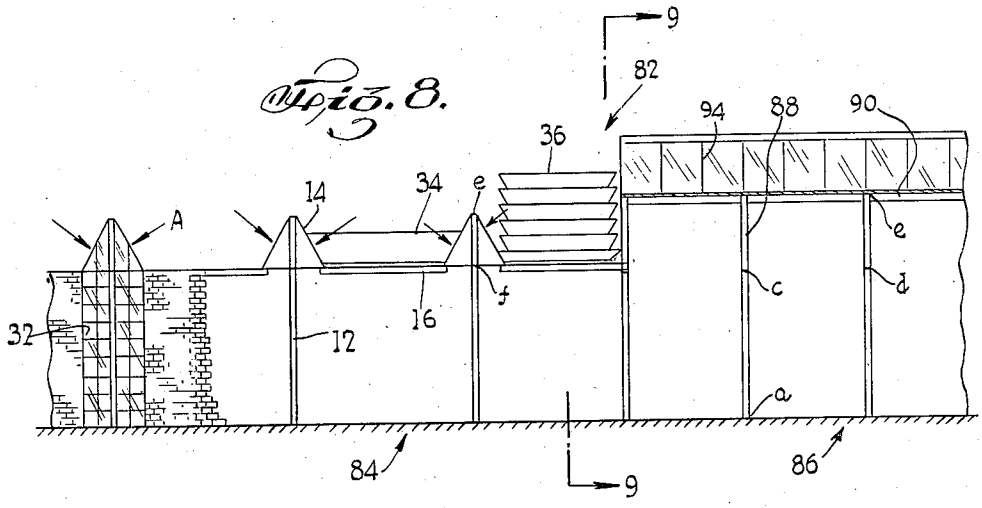
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Fig. 8.



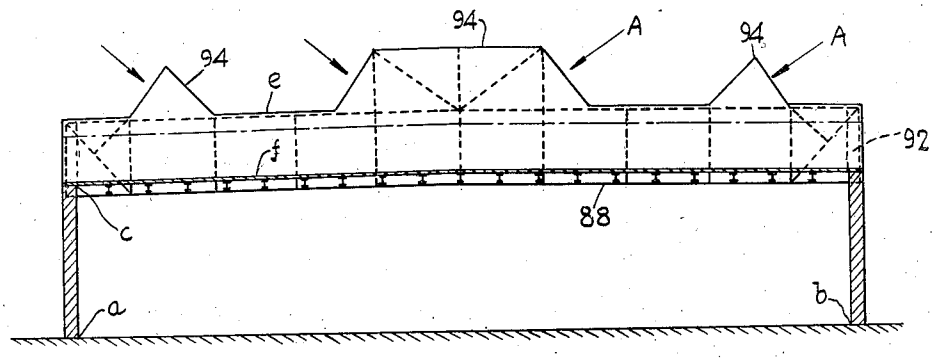


Fig. 9.

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Patented July 31, 1945 2,380,600

UNITED STATES PATENT OFFICE

2,380,600

BUILDING CONSTRUCTION

Jacob Loewenstein, New York, N. Y.

Application November 4, 1943, Serial No. 508,910

9 Claims. (Cl. 108—1)

This invention relates to building constructions and more particularly to the steel work for buildings such as airplane factories, airplane hangars, dirigible hangars, auditorium and the like edifices having wide bays.

Buildings of this type require a spacious area, free of columns, through which large machines like multi-motored bombers and lighter-than-air craft can move, or in which large numbers of people can be assembled and each one assured a clear view of the stage.

Heretofore, the roofs of the bays of these buildings generally comprised a plurality of spaced parallel mono-web trusses which spanned the columns. The term "mono-web truss" as used herein denotes a truss in which the bracing or web members are all disposed in a single plane. As long as the widths of the bays did not exceed sixty feet such mono-web trusses proved satisfactory since they did not have to be made very deep and thus did not create an appreciable dead space beneath the roof, and since mono-web trusses of this length had sufficient inherent rigidity to be easily handled and installed as a unit.

With the advance in the design of airplanes and the growing demand for large auditoriums, the widths of bays have increased to as much as one hundred and forty feet and will probably soon be even greater. However, mono-web trusses are still used in the construction of buildings with such vast bays. These trusses, due to their extreme length, must be made very deep. For example, in a truss having a span of one hundred feet the depth of the truss should be around twelve feet. As a result, the roof of the building, which extends across the top chords of the trusses, is twelve feet above the bottom chords of the trusses, and thus gives rise to a dead or non-utilizable space twelve feet high over practically the entire floor space of the building. This dead space, which must be heated and air-conditioned along with the working space, more than doubles the cost of an air-conditioning plant for a building having a thirty-six foot clear working space beneath the bottom chords of the mono-web trusses.

An additional difficulty has been that, despite their increased depth, mono-web trusses having a span of over sixty feet sway, undulate and even buckle under slight lateral stresses and, therefore, require extreme care in shipping, handling and erection. Thus, a one hundred and forty foot truss has to be shipped in three pieces, each sixty feet or under; during assembly thereof the various parts must be braced, and when lifted into place the entire truss must be braced or guyed. Even after erection such a truss is incapable of holding its own shape until stayed to an adjacent truss. This means that the trusses have to be put up in regular succession so that the last placed truss can be used to stay the next erected truss. Because of this limitation, if, for any reason, one portion of a building temporarily cannot have a roof erected over it, the entire installation of the roof has to be delayed.

It is an object of the present invention to provide an improved building construction in which all of the foregoing defects are avoided and the material and labor costs are decreased.

Another object of the invention is to provide a building construction of the character described in which the overall height of the building is kept at a minimum for the required working height, in which the number of structural pieces employed is less than heretofore, and in which daylight illumination is let into the building through angled skylights without adding any superstructure to the steel work.

A further object of the invention is to provide a building in which each roof truss can be handled as a unit during erection without being braced or guyed and can be placed anywhere in the building without being stayed to an adjacent truss.

Other objects of the invention will in part be obvious and in part hereinafter pointed out.

The invention accordingly consists in the features of construction, combination of elements, and arrangement of parts which will be exemplified in the construction hereinafter described, and of which the scope of application will be indicated in the claims.

In general I accomplish the various objects of my invention by employing a plurality of roof trusses of closed triangular box shape which are so disposed that the ridges of the trusses point upwardly and the bases thereof face the ground, the truss bases in the roof structure being approximately parallel to the ground. The trusses which are interconnected by purlins span a bay between their end supporting columns, said trusses being spaced from and arranged parallel to each other, whereby the distance between columns in the same line is greater than now obtainable since such distance includes not only the span of a purlin but also the width of the bottom web of a box truss. The sloping lateral faces of these trusses can be provided with window sashes so that they serve to admit light to

the interior of the building without the addition of any superstructure to the steel work of the building frame. Also, if desired the portions of the trusses not employed to admit light can be used to house machinery such as air-conditioning units and ducts, or as storage space. The roof of the building having triangular box trusses directly overlies the trusses and between the trusses is supported by the purlins so that the roof is at the general level of the purlins and the bottom chords of the trusses, thus doing away with dead space everywhere except within the trusses, where, as noted, the space is utilized to its fullest extent for storage, the housing of mechanisms, and the passage of light.

In the accompanying drawings, in which is shown one of the various possible embodiments of the invention,

Figs. 1, 2 and 3 are schematic end, plan, and side views, respectively, of a steel building frame embodying my invention;

Fig. 4 is a vertical section through one of the triangular box trusses and shows the manner of connecting the trusses and the purlins;

Figs. 5 and 6 are sectional views taken substantially along the lines 5—5 and 6—6 of Fig. 4;

Fig. 7 is a fragmentary perspective view showing the manner in which an end of one of the triangular box trusses is supported on a column;

Fig. 8 is an end view of a building having its steel frame partly constructed in accordance with the present invention and partly in accordance with conventional practice, the two constructions being shown side by side for purposes of comparison; and

Fig. 9 is a sectional view of the building shown in Fig. 8 taken substantially along the line 9—9 of Fig. 8.

Referring now in detail to the drawings and, more particularly, to Figs. 1, 2 and 3, 10 denotes a building whose steel work or frame, schematically indicated in these figures, is constructed in accordance with this invention. Said steel work comprises, in the main, a plurality of columns 12 firmly bedded in the ground, a plurality of triangular box trusses 14 spanning the columns, and a plurality of purlins 16 between and carried by the trusses.

The columns 12 are arranged in sets or lines, each set running the length of a bay 18, adjacent sets of columns being disposed on opposite sides of the bay. The columns in each set are uniformly spaced apart a distance equal to the breadth of the bottom face of a truss plus the length of a purlin 16, and the columns in adjacent sets are so arranged that the lines joining said pairs of columns extend substantially perpendicular to the length of the bay 18. The outermost set of columns may be set into a brick building wall 20 which, however, need not carry any of the building load. It will be noted from an inspection of Fig. 3 that said wall need run only up to the bottom chords of the trusses 14. Columns in the interior of the building may be enclosed in a protective sheath 22 of concrete or brick.

The triangular box trusses 14 extend across the bay 18, spanning the space between registered pairs of columns in adjacent sets with the longitudinal axis of said trusses disposed perpendicular to the length of the bay 18. The ends of the trusses are carried by the columns 20 which can be connected either to the ridge or the bottom face of the trusses, depending upon the architectural design employed. By virtue of this mounting the trusses are arranged parallel to one another. The columns are spaced apart a distance such that the adjacent bottom chords of juxtaposed trusses are spaced from one another a distance about equal to the length of a conventional purlin, this being approximately twenty feet in airplane factory and airplane hangar construction. It will be understood, however, that, if it is desirable to have purlins of different length, the column spacing may be altered to accommodate the same.

The box trusses are generally triangular in cross-section, the particular shape illustrated being that of an equilateral triangle, although it will be understood that other triangular shapes may be employed as well. Other triangular shapes which will function satisfactorily are scalene triangles wherein both lateral sides slope to an apex above a point in the base of the triangle, that is, neither of the base angles exceeds 90°. However, an isoceles triangle with the two sloping sides of the same length and the base facing the ground is to be preferred to the scalene shape. The two sloping faces or webs of the trusses, and the bottom face or web may be fabricated in any suitable manner, the sloping and bottom faces being permanently joined to each other (prior to use in building construction) to form a triangular box truss.

I have found that a truss of this configuration does not tend to buckle, undulate or sway, the truss being of such design that it is an inherently rigid, slender, elongated structural member of sufficient strength and stiffness, even when built from light elements, to enable it to be lifted as a unit into place with its ends atop two columns without guying or bracing the truss or staying the same to an adjacent truss.

This use of a triangular box truss has other advantages, for example, assuming that erection of the trusses is started at one end of a bay and proceeds regularly to a point where, due, for instance, to foundation trouble or the necessity of covering a machine in another part of the bay, the installation of a few trusses should be momentarily skipped, it is only necessary to move the cranes to the spot where the trusses are to be placed next and the erection can proceed from that point without having to connect the newly installed truss with the last erected truss several columns away. Also, because the truss is self-braced, I can do away with temporary guying and bracing elements during erection and greatly reduce the number of man-hours required to install each truss. I am also able to eliminate temporary shoring or staying of an installed truss before it is permanently tied to an adjacent truss with purlins.

Although I have only shown the center of the trusses as being higher than their ends so as to pitch the roof towards the lines of columns at both sides of a bay, it will be understood that the trusses may be straight and slightly inclined from one line of columns to the other to pitch the roof toward but one line of columns. Likewise, the trusses may be longitudinally arcuate to impart a graceful curve to the roof as where the trusses are employed in an auditorium of a church, theatre or armory. The longitudinal curvature of the truss may even be made so extreme that the two ends of the trusses are almost perpendicular to the ground, in which event the trusses can be used without columns and the ends of the trusses anchored in the ground. This form of construction is particularly useful for

dirigible hangars or for churches having very short buttresses. However, regardless of the profile of the trusses, it is desirable to maintain the trusses parallel and their bottom chords spaced from each other a distance substantially equal to the length of a purlin.

I may also use the trusses as more than mere structural members which only function to aid in carrying the building load. For example, the trusses can be conveniently used as window supporting structure, storage depositories and machinery and conduit supports. These uses of the trusses are schematically indicated in Figs. 1 and 2. In these figures I have indicated windows 24, carried on the sloping side faces of the trusses 14. Said windows, which may be spaced longitudinally of the truss, need not cover the entire height of a side face but only the lower portion thereof. The upper portions of the side faces from the ridges down may house ducts 26 which can be used for air-conditioning and which extend from air-conditioning machinery 28 mounted in the truss between the windows 24. Not all of the space between the windows need be occupied by such air-conditioning machinery and the spaces 30 which are not so employed can be fully enclosed and used as storage bins or the like, particularly for apparatus or parts which might be needed on the roof of the building. If it is more important for appearance or function to have the entire width of the sloping side faces of the trusses employed as windows the air-conditioning machinery, ducts and repositories may be dispensed with and both side faces of the trusses covered with a suitable pellucid material. This light admitting strip can be linearly continued down the walls of the building as indicated at 32 in Fig. 8. The light admitting strips in the walls of the building can be of any conventional construction as, for example, windows mounted in sashes or glass brick. Such continuation of the light admitting strip from the roof of the bay down the walls presents a highly novel and unique appearance and is extremely helpful in illuminating the interior of the building.

Triangular box trusses are capable of carrying and transmitting heavy static roof loads even though composed of relatively light structural elements, and I may utilize this feature to impose permanent heavy roof loads in the form of roof-borne mechanisms which would normally require special bracing, reinforcement or support of the roof. Such mechanisms, by ways of example, may include evaporator pans 34, indicated schematically in Fig. 8, and cooling towers 36 schematically shown in the same figure.

The purlins 16 connect the bottom chords of adjacent triangular box trusses 14. Said purlins run the length of the bay and are spaced from each other across the width of the bay. These purlins serve to support the roof covering therebetween.

It will be appreciated that with a roof structure such as described there is no dead space between the roof covering in the vicinity of the purlins and little or no dead space beneath said covering in the vicinity of the trusses, the only dead space being in the interior of the truss itself, and said space is very small due to the triangular shape of the truss and the absence of any superstructure. Moreover, since the interior of the truss is employed to pass light, to house conduits and air-conditioning apparatus and for storage, to all intents and purposes there is no dead space at all beneath the roof of a building constructed in accordance with my invention.

The triangular box truss 14 may be made in various ways and connected in any one of several manners to the purlins and columns. However, for the purpose of fully explaining the invention, in Figs. 4 through 7 I have shown in detail one manner of constructing and connecting said truss, it being understood that these illustrations are by way of example only and are not to be deemed limitative.

The triangular truss 14 shown in Figs. 4 through 7 consists of two sloping side faces 38, 40 and a bottom face 42. Each side face includes an inclined top chord 44 and bottom chord 46 of channel-shaped configuration. Said chords are secured to each other in spaced parallel relationship by diagonal web bracing members 48 and vertical compression members 50. The diagonal bracing members comprise pairs of angle irons held flange to flange and secured with fish plates 52 to the top and bottom chords 44, 46 and compression members 50. Each compression member is merely a single angle iron secured at its upper end by a fish plate 52 to the top chord 44 and secured directly at its lower end to the bottom chord 46.

The bottom face 42 comprises a plurality of diagonal bracing members 54 and perpendicular bridging compression members 56. The ends of said diagonal and compression members are all tied together and secured to the bottom chords 46 of the opposite sloping faces 38, 40 by a plurality of fish and gusset plates 58. The diagonal web members 54 in the bottom face are secured to each other at their cross-over point by fish plates 59. Thus the bottom face includes as its longitudinal chords the bottom chords 46 of the two sloping faces. It may be mentioned that, for clarity, the diagonal bracing members 54 of the bottom truss faces are schematically indicated in but a few panels of only the leftmost truss 14 in Fig. 2.

The purlins 16 are rigidly and permanently secured to the longitudinal edges of the truss 14 by fish plates 60 which are fixed to the bottom chords 46.

The ridge of the truss is finished off by a capping plate 62 which may be fabricated from a suitable weather resistant material such as asbestos, concrete, copper, or a coated metal. This plate is generally similar to the capping pieces which are presently used on the ridges of building roofs, although it may be of special configuration so that it can fit nicely between the two upper flanges of the top chords 44.

Each sloping truss face 38, 40 also includes an angle iron 62 extending longitudinally of the truss and disposed intermediate the top and bottom chords 44, 46, one of the flanges of the angle iron being spaced outwardly from the lateral diagonal and compression members 48, 50. Cooperating with this angle iron 62 are a plurality of short complementary aligned angle irons 64 which are secured to the bottom chord 46. The long angle iron 62 and short aligned angle irons 64 are adapted to support therebetween window sashes 66 in which are disposed window panes 68. The window panes and sashes may be of any appropriate construction and may be either of the type which permanently maintain a given position or are adapted to be opened and closed so as to allow ventilation.

The roof covering may be of any conventional type as, for example, it can include a plurality of

thick precast concrete slabs 70 laid side by side on the purlins and sloping faces 38, 40 of the trusses and held in position by their own weight, although suitable fastener members may be used, if desired. The layer of concrete slabs is covered by a layer of heat insulating material which may consist of juxtaposed panels 72 of pressed fibrous matter, such as "Celotex." These panels are covered with several layers of tar paper 74 which may be tarred, if desired, to enhance its weather proofing effect.

The manner in which the trusses 14 are mounted on the columns 12 is best shown in Fig. 7. It is there seen that the two top chords 44 of a truss are directly secured, as by bolting, riveting, or welding to the top of the column and that the bottom chords 46 are held to the column by diagonal channel members 76. A bracing member 78 may also be employed, said member extending from a point on the column adjacent where the channels 76 are secured thereto at a point of the upper chord 44 adjacent the top ends of the compression piece 50.

It is also desirable to reinforce the building against deflection of the ends of the column longitudinally of the bay 18 and to this end I may employ sway bracing struts 80 which extend diagonally between an endmost purlin and a beam 81 running between adjacent columns in the same line. These struts and beams lie in the plane of the purlins.

It may be mentioned that, although I have shown the top of a column connected to the ridge of an end of a triangular truss, the top of the column may be connected with equally good results to the bottom face 42 of a truss, in which case the portions of the top chords 44 extending from the last compression member to the column are eliminated.

By way of comparison, in Figs. 8 and 9 I have shown a building 82 which includes one section 84 whose steel framework is erected in accordance with my invention and another portion 86 whose steel framework is erected in a fashion now conventionally employed in the art. The dash-and-dot lines in Fig. 9 represent portions of the section 84 not seen in the section taken along the line 9—9 of Fig. 8. Typical dimensions of the working space in both of these sections and of the length of the purlins will be assumed by way of example.

Each of these two sections is to have a bay one hundred feet wide, that is, one hundred feet from *a* to *b*. The bays are to have a clear working space thirty-six feet high, that is, the distance from *a* to *c*. The purlins are to be twenty feet long. The sections are to be illuminable by sunlight.

The old building section 86, if using conventional design, would employ mono-web trusses 88 having a depth of about twelve feet, that is the distance from *d* to *e* exclusive of the purlins 90. The roof of the old section is laid on top of said purlins and is, therefore, a minimum distance of forty-eight feet from the ground. This means that there is a minimum dead space of twelve feet all over the bay of the old section. The brick walls 92 for this section 86 must be brought up to the top of the mono-web trusses 88 in order to fully enclose the interior of the building so that the brick walls will also be forty-eight feet high. On top of the purlins monitors or skylights 94 of standard design must be placed. These skylights, which require the use of superstructure, will be about eight feet high so that, in addition to the twelve feet of dead space created by the use of mono-web trusses, in certain portions of the building, constituting more than one-half of the floor space, an additional eight feet of dead space will be added. The overall height of the building will be fifty-six feet. The distance between the columns 94 on which the mono-web trusses 88 are carried is approximately twenty feet, the length of the purlins. The number of structural elements required to be assembled in the field during the erection of a unit length of the old section 86 is about 8,000 pieces.

In the section 84 of the building, constructed in accordance with the instant invention, the distance from the base of the triangular box truss 14 to its ridge, i. e., the distance *ef*, should be about ten feet for a one hundred foot span, so that the breadth of one of the lateral faces 38, 40 of the truss, which is of equilateral shape, is approximately eleven and one-half feet. Since the purlins are connected to the bottom apices of the trusses 14 and the roof is on the purlins, there will be no dead space between the trusses, and the only dead space that can be present is inside the trusses themselves, although as pointed out above, this space can be utilized, because of the inherent rigidity of the triangular box trusses. In other words, the structural members surrounding this space reinforce each other sufficiently to permit carrying a working load inside the truss without the use of heavier or additional members. The windows in the trusses provide an illuminating area as great as that offered by the skylights 94, but the light entering in the direction of the arrow A is closer to the ground and, therefore, more effective.

The overall height of the section 84 is ten feet plus thirty-six feet or forty-six feet in all, compared to the overall height of fifty-six feet for the building section 86.

The space between columns of the building section 84 is the length of a purlin plus the width of the bottom face of the triangular trusses or about thirty-one and one-half feet, compared with twenty feet for the column spacing in the building section 86. The purlins in the building section 84 are discontinuous whereas the purlins in the building section 86 are connected to each other through the mono-web trusses. Thus I am able to effect an appreciable saving in the weight of the structure insofar as the purlins and columns are concerned. This saving is, of course, somewhat offset by the extra weight of the triangular box trusses but an overall slight reduction in weight is obtained.

Of great importance is the fact that because the trusses are self-braced, they can be shipped in larger pieces than the mono-web trusses and erected without bracing, guying, or staying.

The number of structural elements in the building section 84 for a unit length is only about 3000 pieces. It should also be noted that the wall of the building portion 84 is only thirty-six feet high, a saving of twelve feet.

It will thus be seen that I have provided a building construction which has many advantages over those heretofore employed and which may be erected in less time and with considerable less labor and that said construction achieves the several objects of the present invention and is advantageously adapted to meet all conditions of present-day use.

As various possible embodiments might be made of the above invention, and as various changes might be made in the embodiment above set

forth, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

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

1. A permanent building construction capable of carrying heavy live and dead loads, said construction comprising a plurality of trusses, each at least sixty feet long, which span the width of a bay and are spaced from each other along the length of the bay, each said truss being composed of a plurality of structural members rigidly and permanently interconnected to provide three mono-web trusses, each mono-web truss being rigidly and permanently connected to both of the others, so as to form a closed triangular box truss having two side faces meeting at a ridge and a base meeting the side faces at base apices, means to permanently support each end of each box truss, structural members rigidly and permanently interconnecting the base apices of adjacent triangular box trusses intermediate the ends thereof, and a roof covering on the outside of the framework defined by said structural members and the side faces of the box trusses.

2. A permanent building construction capable of carrying heavy live and dead loads, said construction comprising a plurality of trusses, each at least sixty feet long, which span the width of a bay and are spaced from each other along the length of the bay, each said truss being vertically supported at both ends thereof by columns and being composed of a plurality of structural members rigidly and permanently interconnected to provide three mono-web trusses, each mono-web truss being rigidly and permanently connected to both of the others, so as to form a closed triangular box truss having two side faces meeting at a ridge and a base meeting the side faces at base apices, structural members rigidly and permanently interconnecting the base apices of adjacent triangular box trusses intermediate the ends thereof, and a roof covering on the outside of the framework defined by said structural members and the side faces of the box trusses.

3. A permanent building construction capable of carrying heavy live and dead loads, said construction comprising a plurality of trusses, each at least sixty feet long, which span the width of a bay and are spaced from each other along the length of the bay, each said truss being composed of a plurality of structural members rigidly and permanently interconnected to provide three mono-web trusses, each mono-web truss being rigidly and permanently connected to both of the others, so as to form a closed triangular box truss having two side faces meeting at a ridge and a base meeting the side faces at base apices, the ridges of all the box trusses pointing upwardly and the bases thereof facing the ground, a row of columns running along each side of the bay, said box trusses being supported on both ends thereof on said columns, purlins rigidly and permanently interconnecting the base apices of adjacent box trusses intermediate the ends thereof, and a roof covering on the outside of the framework defined by said purlins and the side faces of the box trusses.

4. A building construction as set forth in claim 3 wherein the box trusses are equilateral in cross-section.

5. A building construction as set forth in claim 3 wherein the trusses are isosceles in cross-section and the lateral equal faces slope upwardly to the truss ridges.

6. A building construction as set forth in claim 3 wherein a plurality of box trusses have both lateral faces sloped and carrying windows.

7. A building construction as set forth in claim 3 wherein the purlins are discontinuous along the length of the bay.

8. A building construction as set forth in claim 3 wherein each box truss is supported at one end thereof by a single column.

9. A building construction as set forth in claim 3 wherein each box truss is supported at one end thereof by a single column and wherein the ends of said trusses are tapered toward said columns.

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