Oct. 7, 1941. S. SZEGÖ 2,257,770

BEAM GRID

Filed Nov. 30, 1940 2 Sheets-Sheet 1

Fig. 1

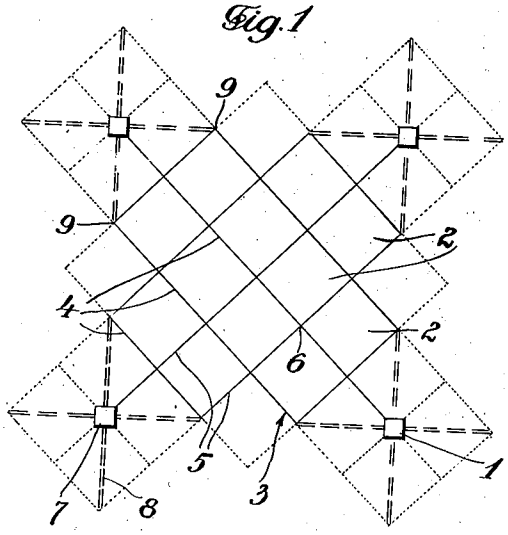


Fig. 2

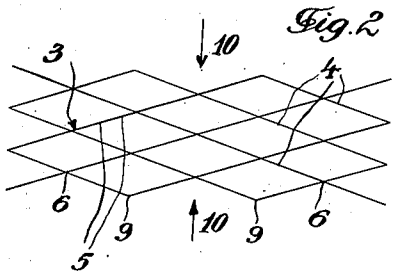


Fig. 3

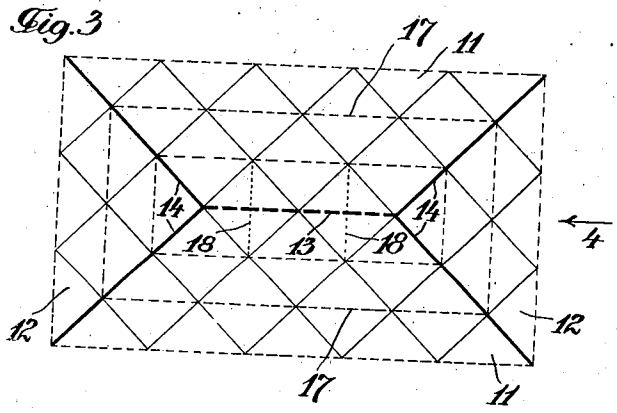


Fig. 4

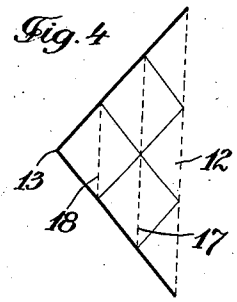


Fig. 5

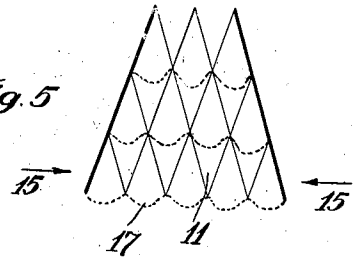
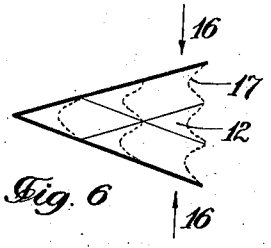


Fig. 6



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BEAM GRID

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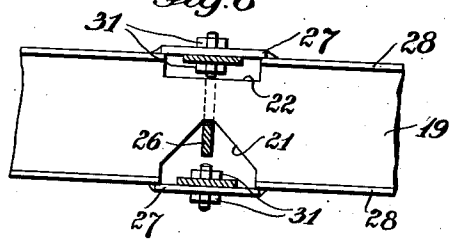
Fig. 8



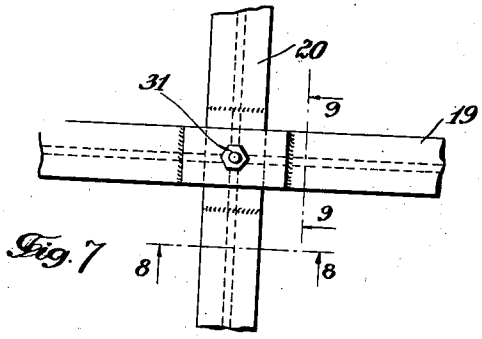


Fig. 7

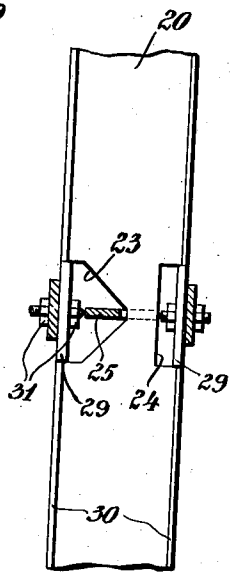


Fig. 9

Fig. 11

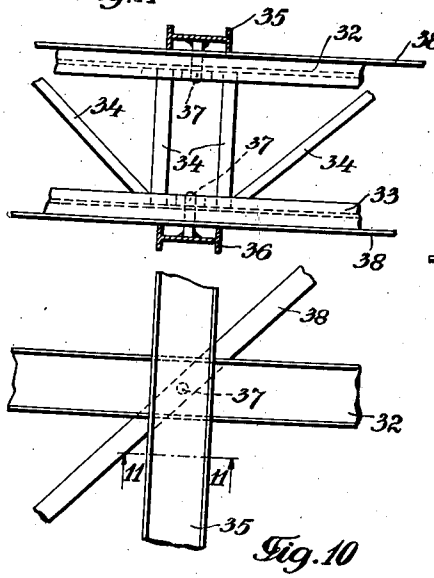


Fig. 10

Fig. 12

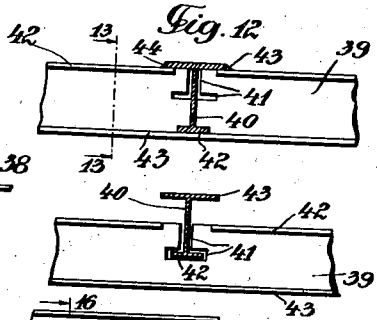


Fig. 13

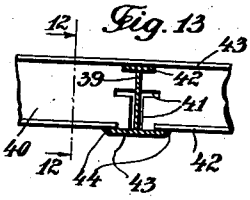
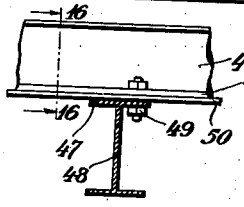


Fig. 14

Fig. 15



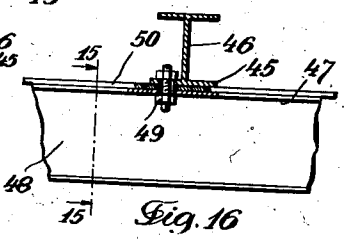


Fig. 16

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UNITED STATES PATENT OFFICE

2,257,770

BEAM GRID

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Application November 30, 1940, Serial No. 368,014
In Switzerland January 5, 1940

19 Claims. (Cl. 108—1)

My present invention relates to improvements in beam grids and more particularly to beam grids for roof and floor structures comprising two groups of beams intersecting each other and being interconnected at regularly spaced nodes.

The main object of my invention is to provide shop completed ready made beam grids which can be easily transported from shop to building site and erected there in the position required for the finished structure.

A further object of my present invention consists in beam grid structures being foldable during transportation and being adapted to be reshaped at the site where the grid structure has to be erected without use of additional members or assembling by simply extending the grid into the shape and size needed for the respective structure.

Thus, it is another object of my present invention to provide grid beams for roof and floor structures which are adapted to be used temporarily, e. g. for non-permanent buildings, such as aeroplane hangars for expeditionary forces or the like, which should be adapted to be transported, erected and dismantled quickly and without difficulty and re-used again in the same way on other sites.

Still another object of my invention consists in providing a grid beam unit which can be used within limits for covering differently shaped and sized areas.

In accordance with my present invention I obtain the above objects by providing a beam grid for roof and floor structures which comprises two groups of beams intersecting each other at a series of grid nodes, and means connecting these beams at said grid nodes movably to each other, enabling thereby variation of the angle of intersection of said beams in their mutual plane without noticeably reducing the inertia of the beams and folding of the entire beam grid, if required. In most cases I have to provide further means which are adapted to fix the horizontal distance of the grid nodes to each other with the required length, increasing simultaneously the stability and strength of the entire grid structure without limiting its foldability.

It is evident that by varying the angle of intersection between the beam groups of a grid I am able to vary within limits the size and shape of the area covered by this grid. Thus, for instance, a beam grid adapted to cover a square-shaped area is also adapted to cover quadrangular areas of similar size. Thus, for instance, a beam grid, originally rated for an area of 90 x 90 feet, can be used without any rebuilding for an area of e. g. 75 x 108 feet. This feature of my new beam grid makes it possible to store only a restricted amount of finished beam grids and, nevertheless, be able to meet requirements for most different grid sizes. During storage the whole grid unit is folded into a grid "stick," thus needing small space and being easily transportable.

If the area to be covered is of too large a size to be covered by one grid it can be subdivided by supporting members, e. g., interior columns within said area, or the roof can be subdivided into similarly shaped units extending from one interior valley to the next interior valley in either direction and being cranked alternately upwards and downwards; in this case I propose to provide separate grid units for each subdivision of the roof. If required, these subdivided units may be connected to each other along one contacting edge by hinge-like means, enabling thereby folding of the entire roof structure, or part of it, along these edges.

The novel features which I consider as characteristic for my invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its methods of operation, together with additional objects and advantages thereof will be best understood from the following description of specific embodiments, when read in connection with the accompanying drawings, in which:

Fig. 1 shows a beam grid unit for continuous floors being supported by columns;

Fig. 2 shows the grid unit shown in Fig. 1 in its folded form;

Fig. 3 shows a roof structure according to my present invention;

Fig. 4 is a view of the roof structure shown in Fig. 3, seen in direction of arrow 4;

Fig. 5 is an elevational view of the roof structure shown in Fig. 3, in its folded form;

Fig. 6 is another elevational view of the roof structure shown in Fig. 3, in its folded form;

Fig. 7 shows a plan view of a beam construction with cut-outs in the beam webs and flanges;

Fig. 8 shows a cross-section of the connection shown in Fig. 7, along line 8—8 of Fig. 7;

Fig. 9 shows a cross-section of the connection shown in Fig. 7, along line 9—9 of Fig. 7;

Fig. 10 is a plane view of another turnable grid connection;

Fig. 11 is a cross-section of the grid connection shown in Fig. 10, along line 11—11 of Fig. 10;

Fig. 12 is a cross-section of a beam connection

provided with slits in the beams, along line 12—12 of Fig. 13;

Fig. 13 is a cross-section of the beam connection shown in Fig. 12, along line 13—13 of Fig. 12;

Fig. 14 is a plane view of the connection shown in Figs. 12 and 13, during folding;

Fig. 15 is a cross-section of the beam connection shown in Fig. 16, along line 15—15 of Fig. 16, and

Fig. 16 is a cross-section of the beam connection shown in Fig. 15, along line 16—16 of Fig. 15;

As shown in Fig. 1, a floor or roof structure according to my present invention comprises supporting means 1 consisting of cantilevers 8 connecting interior columns 7 or the like within the area of the structure, forming thereby rectangular bays 2 lying between these supporting means; my new structure furthermore comprises a series of beam grid units 3, each of which is adapted to cover one of said rectangular bays 2 and is supported by the corresponding cantilevers 8 atop of the interior columns 7; each of these beam grid units comprises two groups of parallelly arranged beams, the beams 4 of one beam group being arranged intersecting the beams 5 of the other beam group at a series of grid nodes 6; means, not shown in Fig. 1, are arranged for connecting these beams 5 and 6 at these grid nodes 6 movably to each other in their mutual plane, thereby enabling variation of the angle of intersection of said beams and folding of the entire beam grid, if required. In most cases it is necessary to provide means being adapted to fix the grid beams 4 and 5 at the grid nodes 6 to each other in the required position. The connecting and fixing means are shown and described in detail in Figs. 7–16 of the drawings and the corresponding part of my description.

I prefer to arrange the supporting means of the structure at substantially equal distances from each other, thus forming rectangular bays of substantially equal spans; this gives me the possibility to use equally shaped, i. e., standard grid units for all bays of the structure. I have found it most advantageous to arrange the supporting means in such a manner that they form square-shaped intermediate bays 2 of equal size between them; this enables not only the use of equally shaped grids, but makes it possible to fix the grids to the supporting columns in different positions, as the square-shaped grid unit can be placed on the square-shaped supporting means, fully covering the square-shaped area within these supporting means, in four different ways.

As supporting means columns, beams, walls or the like may be used. For covering large areas I prefer the use of supporting columns 7 provided with cantilevers 8 or the like arranged in direction of the edges of the interior bays of the respective structure. As shown in the drawing, these cantilevers 8 serve for supporting the grid nodes 9 lying along the edges, and not in the corners, of the grid units.

Fig. 2 shows the grid unit 3 in its partly telescoped form. By loosening the fixing means arranged at the grid nodes and by exerting pressure in direction of the arrows 10 the grid unit can be folded as shown. It is evident that it is much easier to transport the grid unit in this folded form than in its extended form, needed for the erected structure.

Fig. 3 shows a roof structure built in accordance with my present invention. This roof structure comprises oppositely disposed roof planes 11 and 12, respectively, intersecting each other and forming thus a roof ridge 13, and sloping roof hips 14; the grid unit forming this roof structure comprises four grid parts forming each of the four roof planes 11 and 12 of the structure. In the embodiment of my invention shown in the drawings, each part of this grid unit may be built separately, but before folding they are interconnected along the roof hips 14.

The means of inter-connection are not shown in the drawings; they may consist of welding, bolts or the like.

Each of the roof parts comprises two groups of beams intersecting each other; these beam grids are built and the beams of the grids connected to each other in the same manner as described above in connection with the beam grid shown in Figs. 1 and 2. For transport and storage these beam grid units are folded by first folding the two trapezoid-shaped beam grid parts 11 in the direction indicated in Fig. 5 by arrows 15, and thereafter folding the triangular beam grid parts 12 by exerting pressure in direction of arrows 16—16 as shown in Fig. 6. I want to note that it is, however, also possible to fold first the grid parts 12 and thereafter the parts 11, if required.

It should be noted that it is not only possible to cover roofs in the manner shown in Fig. 3; I may cover large areas by providing a roof structure comprising preferably equal interior bays; in this case each of the interior bays is covered by a separate grid unit; two or more of these grid units may be connected to each other by hinge-like means at their edges contacting in the finished roof structure.

As proposed in my prior application Ser. No. 356,947, filed September 16, 1940, I may provide in the roof structure shown in Figs. 4–6 for reinforcing the grid structure ties 17 connecting all grid nodes lying at the same horizontal level. In foldable grids, according to my present invention, I may use straight or "broken" beams, as shown in Fig. 7 of the above cited application, and connect them at their intersecting points; in case "broken" beams are used for my foldable grids, these beams are connected to each other at the points at which they are "broken," in the manner described above. If ties are used for such foldable grids, it is of utmost importance that these ties 17 should be flexible or shiftable as otherwise it would be impossible to fold the grids.

I may furthermore provide additional reinforcing straps 18 connecting grid nodes of the oppositely arranged grid parts 11; these additional straps 18 should be arranged in such a way as to connect grid nodes lying at the same horizontal level. They should also be arranged normal to the direction of the ridge 13 of the roof structure.

As evident from Fig. 5, it is impossible to use a permanent ridge for the foldable roof structure as this would make folding of the structure impossible. Therefore, I propose to use in combination with my new roof structure a removable ridge beam adapted to resist compression and to withstand bending moments; this ridge beam should be mounted separately on the ridge of the roof structure after reshaping of the grid in the manner required for the finished roof structure.

Furthermore, I have found it of advantage in special types of grid structures to arrange the reinforcing members 17 and 18 which connect grid nodes lying at the same horizontal level, in

such a manner that they have purposely differing lengths, so that the longer ones only begin to carry load stresses after expansion of the originally shorter ties to the same length under their loads. This makes it possible to equalize the distribution of stress in each member of the grid unit.

The following figures show preferred embodiments of beam connections, being especially adapted for my new beam grids. As shown in Figs. 7–9, the beams 19 and 20 are provided with cut-outs 21, 22 and 23, 24, respectively. The cut-outs 21 and 23 are arranged in such a way that the web 25 remaining between the cut-outs 21 and 22 fits into cut-out 23, as shown in Fig. 9; and, vice versa, the web 26, remaining between the cut-outs 23 and 24 fits into cut-out 21, as shown in Fig. 8. These webs are not connected with each other. The sole connection between the beams 19 and 20 is maintained by connecting flange plates 27 welded to the outer surface of the flanges 28 of beam 19 and by connecting flange plates 29 welded to the flanges 30 of beam 20 preferably flush with their outer surface. As shown in the drawings, corresponding openings are provided for in these connecting flange plates, and screws 31 passes through these openings movably, e. g. turnably connecting the beams 19 and 20.

In the grid connection shown in Figs. 10 and 11 instead of single beams, entire open web trusses are used; one of these trusses comprises an upper cord 32, a lower cord 33, and bracings 34 connecting the upper and lower cords 32 and 33. The construction of the intersecting grid beam may be an identical one. In this case it is only necessary to arrange the upper and lower cords of one grid beam in such a way that the inner distance between the flanges of these cords is equal to the outer distance between the flanges of the cords of the intersecting beams, i. e. it must be possible to insert one grid beam within the other, as shown in Fig. 11. It is, however, also possible to use only one single cord 35 or 36 as grid beams instead of an open web truss comprising the upper cord 35 and lower cord 36. The cords of the trusses of the grid beams themselves may consist of I-beams, channels, angles or other structural shapes, interconnected by screws 37 or like connecting members. Flexible reinforcing straps 38 may also be connected to the beams by the same screws 37, as shown in Fig. 10. Such straps may consist of rolled strips, flats, bars, wires, ropes, chains, cables, or the like.

Figs. 12 to 14 show still another connection type. In this embodiment each of the beams 39 and 40 is provided with equal, half-notched, partly slit-shaped, cut-outs 41. It should be noted that I prefer to use beams having differently sized top and bottom flanges for grids connected by the means shown in these figures. The top flange 42, in which the cut-out 41 is provided, is narrower than the bottom flange 43. Consequently, if the cut-out of one beam is fitted into the cut-out of the other beam and thus the beams themselves fitted together, as shown in Figs. 12 and 13, it causes an overlapping of the bottom flange 43 over the cut-out 41 in the top flange 42. In this position they can be fixed easily to each other by welding seams 44 along the contacting edges between the bottom flanges 43 and the top flanges 42 under the angle required for the finished roof. Using this type of connection, the beam grid may be telescoped easily if the beams are in the relative position shown in Fig. 14; this can, however, be done only before welding the grid beams together in final position.

Figs. 15 and 16 show a very simple and effective beam connection. In this construction the flange 45 of beam 46 is in close contact with flange 47 of the intersecting beam 48. Attaching means, e. g. screws 49 are provided which secure the contacting flanges 45 and 47 outside of the central line of the contacting flanges to each other. For this purpose the screw holes are made outside of the central line of the flanges, as shown in these figures. If necessary, the flexible reinforcing straps 50 may be secured between the flanges 45 and 47. Channels, angles or other structural shapes in horizontal or vertical position may be used instead of the I-beams 46 and 48.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of floor and roof structures differing from the types described above. For instance, the roof units may have only two folded parts, i. e., they may be of a single pitch type, or they may have more than four parts per unit, as in the case of arched or domed grids.

While I have illustrated and described the invention as embodied in floor and roof structures, I do not intend to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of my invention.

Without further analysis, the foregoing will so fully reveal the gist of my invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention, and therefore such adaptations should and are intended to be comprehended within the meaning and range of equivalency of the following claims.

What I claim as new and desire to secure by Letters Patent is:

1. Beam grid for roof and floor structures comprising two groups of beams, the beams of one beam group being arranged intersecting the beams of the other beam group at a series of grid nodes, and means movably connecting said beams at said grid nodes to each other, thereby enabling variation of the angle of intersection of said beams in their mutual plane and folding of the entire beam grid, if required.

2. Beam grid for roof and floor structures, comprising two groups of beams, the beams of one beam group being arranged intersecting the beams of the other beam group at a series of grid nodes, means movably connecting said beams at said grid nodes to each other, and means being adapted to fix said grid beams at said grid nodes in the required relative position to each other, thereby enabling variation of the angle of intersection of said beams in their mutual plane and folding of the entire beam grid, if required.

3. Beam grid for floor and roof structures, comprising two groups of beams, the beams of one beam group being arranged intersecting the beams of the other beam group at a series of grid nodes, means adjustably connecting said beams at said grid nodes to each other, and means being adapted to fix said grid beams at said grid nodes in the required relative position to each other, thereby enabling variation of the angle of inter-

section of said beams in their mutual plane and folding of the entire beam grid, if required.

4. Beam grid for floor and roof structures, comprising two groups of beams, the beams of one beam group being arranged intersecting the beams of the other beam group at a series of grid nodes, and means turnably connecting said beams at said grid nodes to each other, thereby enabling variation of the angle of intersection of said beams in their mutual plane and folding of the entire beam grid, if required.

5. Floor and roof structure comprising supporting means disposed along the edges and within the area of said structure, forming thereby structural bays lying between said supporting means, a series of beam grid units, each of said units being adapted to cover one of said structural bays and being supported by the corresponding supporting means, each of said beam grid units comprising two groups of parallel beams, the beams of one beam group being arranged intersecting the beams of the other beam group at a series of grid nodes, means movably connecting said beams at said grid nodes to each other, and means being adapted to fix said grid beams at said grid nodes in the required relative position to each other, thereby enabling variation of the angle of intersection of said beams in their own plane and folding of each beam grid unit, if required.

6. Floor and roof structure comprising supporting means arranged along the edges and within the area of said structure at substantially equal distance from each other, thus forming structural bays of substantially equal shape lying between said supporting means, a series of equally shaped beam grid units, each of these units being adapted to cover one of said structural bays and being supported by the corresponding supporting means, each of said beam grid units comprising two groups of parallel beams, the beams of one beam group being arranged intersecting the beams of the other group at a series of grid nodes, and means movably connecting said beams at said grid nodes to each other, thereby enabling variation of the angle of intersection of said beams in their mutual plane and folding of each beam grid unit, if required.

7. Floor and roof structure comprising supporting means arranged along the edges and within the area of said structure at substantially equal distance from each other in such a manner that they form square-shaped structural bays between them, a series of equally shaped beam grid units, each of these units being adapted to cover one of said structural bays and being supported by the corresponding supporting means, each of said beam grid units comprising two groups of parallel beams, the beams of one beam group being arranged intersecting the beams of the other group at a series of grid nodes, and means movably connecting said beams at said grid nodes to each other, thereby enabling variation of the angle of intersection of said beams in their mutual plane and folding of each beam grid unit, if required.

8. Floor and roof structure, comprising columns supporting cantilevers arranged along the edges and within the area of said structure, thus forming a series of structural bays lying between said supporting columns and said cantilevers, a series of beam grid units, each of these units being adapted to cover one of said structural bays and being supported by corresponding supporting columns and cantilevers, each of said beam grid units comprising two groups of parallel beams, the beams of one beam group being arranged intersecting the beams of the other beam group at a series of grid nodes, and means movably connecting said beams at said grid nodes to each other, thereby enabling variation of the angle of intersection of said beams in their mutual plane and folding of each beam grid unit, if required.

9. In a floor and roof structure, according to claim 8, columns supporting cantilevers arranged in direction of the edges of the structure bays.

10. Roof structure of the single pitch type comprising oppositely disposed roof planes intersecting each other and forming thus a roof ridge, said roof structure comprising one beam grid unit consisting of two grid parts forming said roof planes, hinge-like means turnably connecting said grid parts along said roof ridge, thereby enabling variation of the angle enclosed by said grid parts, each of said roof grid parts comprising two groups of parallel beams, the beams of one beam group being arranged intersecting the beams of the other beam group at a series of grid nodes, and means movably connecting said beams at said grid nodes to each other, thereby enabling variation of the angle of intersection of said beams in their mutual plane and folding of both grid part and the entire roof grid, if required.

11. Beam grid unit for a rectangular roof structure consisting of two pairs of oppositely disposed roof planes intersecting each other and forming thereby sloping roof hips and a roof ridge, said beam grid unit comprising four grid parts forming the four roof planes of the roof structure, hinge-like means for turnably connecting said grid parts to each other at said roof hips, each of these grid parts comprising two groups of parallel beams, the beams of one beam group being arranged intersecting the beams of the other beam group at a series of grid nodes, and means movably connecting said beams at said grid nodes to each other, thereby enabling variation of the angle of intersection of said beams in their mutual plane and folding of all beam grid part and the entire beam grid unit, if required.

12. Beam grid unit for a rectangular roof structure consisting of two pairs of oppositely disposed roof planes intersecting each other and forming thereby sloping roof hips and a roof ridge, said beam grid unit comprising four grid parts forming the four roof planes of the roof structure, hinge-like means for turnably connecting said grid parts to each other at said roof hips, each of these grid parts comprising two groups of parallel beams, the beams of one beam group being arranged intersecting the beams of the other beam group at a series of grid nodes lying in the finished roof structure at the same horizontal level, means movably connecting said beams at said grid nodes to each other, flexible reinforcing ties being adapted to carry tensile forces only connecting grid nodes of said beam grid unit lying at the same horizontal level, and means connecting said beams and said reinforcing ties at said grid nodes movably to each other.

13. Beam grid unit for a rectangular roof structure consisting of two pairs of oppositely disposed roof planes intersecting each other and forming thereby sloping roof hips and a roof ridge, said beam grid unit comprising four grid parts forming the four roof planes of the roof structure, two of these roof grid parts being

trapezoid-shaped and two of them having a triangular shape, hinge-like means for turnably connecting said grid parts to each other at said roof hips, each of these grid parts comprising two groups of parallel beams, the beams of one beam group being arranged intersecting the beams of the other beam group at a series of grid nodes lying in the finished roof structure at the same horizontal level, means movably connecting said beams at said grid nodes to each other, flexible reinforcing ties being adapted to carry tensile forces only connecting grid nodes of said beam grid unit lying at the same horizontal level, and means connecting said beams and said reinforcing ties at said grid nodes movably to each other.

14. In a beam grid unit according to claim 13, additional flexible reinforcing straps connecting grid nodes of the oppositely arranged trapezoid-shaped grid parts, said additional reinforcing straps being arranged in such a manner as to extend in the finished roof structure normal to the direction of the ridge.

15. In combination with the beam grid unit claimed in claim 10, a removable ridge beam adapted to resist compression and to withstand bending moments, said ridge beam being mounted separately on the ridge of the erected roof structure.

16. In combination with the beam grid unit claimed in claim 11, flexible reinforcing ties connecting grid nodes of said beam grid unit lying at the same horizontal level, said flexible ties being arranged in such a manner that they have purposely differing lengths, so that the longer ones only begin to carry load stresses after expansion of the originally shorter ties to the same length under their load.

17. In a foldable beam grid unit a connection for two grid beams intersecting each other, said connection comprising cut-outs in said beams at their axis of intersection, said cut-outs being arranged in such a manner that the remaining webs can turn freely around said axis of intersection without being connected, while the corresponding flanges of said beams are superposed on each other, and attaching means turnably connecting said superposed flanges.

18. In a foldable beam grid unit a turnable connection for two grid beams intersecting each other, said connection comprising two beams provided with slits in said beams at their axis of intersection, said slits being made normal to the longitudinal direction of said beams and extending at least until the middle of the height of the beams, said beams being fitted one into another by these slits at their axis of intersection.

19. In a foldable beam grid unit a turnable connection for two grid beams intersecting each other, said connection comprising two beams provided with slits in said beams at the axis of intersection, said slits made normal to the longitudinal direction of said beams and extending at least until the middle of the height of the beams, said beams being fitted one into another by these slits at their axis of intersection, and the flanges of the beams being fixed to each other in the position obtained by said fitting at the angle required for the finished beam grid.

STEVEN SZEGÖ.