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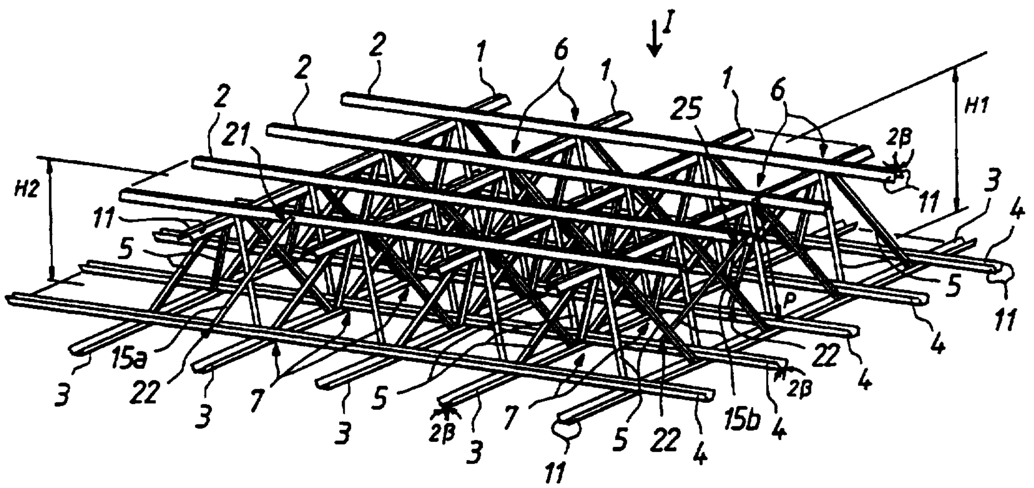

(57) Abstract

The invention relates to a space frame structure without nodes, the structure comprising first (1) and second (2) continuous upper chord profiles running crosswise relative to each other and first (3) and second (4) continuous lower chord profiles running crosswise relative to each other, as well as diagonal profiles (5) which connect junction points (6) of the upper chord profiles to junction points (7) of the lower chord profiles, whereby nodes are formed at which the diagonal profiles are connected to the chord profiles. Both the first and the second upper chord profiles, as well as the first and the second lower chord profiles, comprise each two flat flanges (11) which together form an apex angle (2β). The diagonal profiles (5) comprise each two continuous side surfaces which mutually form a spread angle. At the nodes (6, 7) the diagonal profiles (5) are by their side surfaces directly secured to both the first and the second upper chord profiles (1, 2) and, respectively, to both the first and the second lower chord profiles (3, 4), to their continuous flat flanges (11).

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Space truss structure without node pieces

The invention relates to a space frame structure without node elements, which frame structure comprises first and second continuous upper chords running crosswise in relation to each other and first and second continuous lower chords running crosswise in relation to each other, as well as diagonal profiles which connect at least some of the junction points of the upper chord profiles to at least some of the junction points of the lower chord profiles, whereby there are formed space frame structure nodes at which the continuous side surfaces of the diagonal profiles are fastened to at least one of the chord profiles.

By a space frame structure is thus meant in the present patent application a frame structure which has upper chords and lower chords forming an upper chord grid or upper chord grids and, at a distance from this, a lower chord grid or lower chord grids. In principle such a space frame can thus, in the orientation of these grids, be extended indefinitely by lengthening the members which constitute the upper and lower chords and by increasing their number in the transverse directions. Such a space frame structure thus has a length of the required magnitude and a width of the required magnitude and, perpendicular to these, a thickness substantially smaller than both the length and the width of the space frame structure. Across the length of the space frame structure there run at least two chord members and across its width there run at least two chord members which intersect the first-mentioned chord members. The invention thus relates to plate-like space frame structures and does not at all deal with pillar or beam structures having a thickness and a width limited by the design of the structure and having only one dimension, i.e. the length, extendable in an unlimited manner. Plate-like space frame structures normally comprise a plurality of first and second upper chord profiles which run crosswise relative to each other, and a plurality of first and second lower chord profiles which run crosswise relative to each other. The junction points of the upper chord profiles are in one such space frame structure connected to the junction points of the lower chord profiles by using diagonal braces, in which case nodes are formed at the junction points of the diagonal braces and these chord profiles. The diagonal braces interconnecting these nodes thus maintain the upper chord profiles and the lower chord profiles at a distance from each other which is the characteristic thickness of the space frame structure, and also mediate forces between the chord profiles. Typically these nodes are formed at the junction points of the chord profiles, but such nodes may be formed with diagonal braces also at other points of the chord profiles. In general, a plurality of diagonal braces are connected to one node, for example typically four diagonal braces which are oriented from the node symmetrically and pyramidally in different directions towards opposite chords. Depending on the placement of these diagonal braces, and thus the placement of the nodes, and on the orientation of the diagonal braces, numerous different space frame structure geometries are obtained, which are known per se.

If we start from the space frame structure principle described above, it is evident that a space frame can be formed from separate node elements and from separate bars which interconnect the node elements, the bars in the upper chord grid and the bars in the lower chord grid forming lines, and thereby the chord members, and the bars interconnecting the chords forming the diagonal braces. This system has the advantage that each bar can be designed and manufactured on the basis of the loads the frame element concerned will be subjected to. Thus the bars in different orientations are in these systems typically different. Such space frame structures equipped with node elements have been described in publications FI-80 935, FI-92 508 and DE-2 413 529. However, owing to the complicated structure of the node elements and to the fact that it is necessary to manufacture a large number of different bars to produce the chord members and the diagonal braces, such a frame structure is in practice expensive. Furthermore, since in its assembly it is necessary to take into account the fact that the different bars fit in only certain places and in certain positions, the assembling of such a frame structure with node elements is also complicated and time-consuming. Costs are also increased by the fact that bars manufactured for a certain individual space frame structure usually cannot be used for any other space frame structure; each frame must be made from structural parts specifically designed and prepared for it. Therefore the costs are further increased by the fact that no serial production or continuous production is possible. Publication CH-429 086 also describes a frame structure in which node elements are used, although in this structure the node elements are either plate-like pieces or parts of a T-profile and thus simple in shape. This structure contains a very large number of parts and its manufacture and assembling are expensive. What is obtained by using this proposed construction is not a genuine space frame structure but a combination of parallel and/or intersecting flat grids.

Publications US-5 165 214 and EP-128 431 describe space frame structures without node elements, these structures thus comprising continuous upper chord profiles running crosswise relative each other and continuous lower chord profiles running crosswise relative to each other, and diagonal profiles connecting these chord profiles. In these publications the chord profiles are thus continuous, i.e. they have not been cut into parts having the length of the distance between nodes; they are profile shapes continuing throughout the upper chord and the lower chord. In order that the ends of the diagonal profiles could be secured to the continuous chord profiles, the ends of the diagonal profile pieces are bent and, when necessary, also otherwise shaped, for example by flattening, in which case the diagonal profiles can be secured to the chord profiles by using bolts. The fact that it is not necessary to manufacture separate complicated node elements and that the chord profiles can be continuous profiles makes these space frame structures more advantageous than the frame structures using node elements, described above. However, the frame structure described in the said EP publication requires that the chord profiles be notched in order that they can be fitted to each other at the junction points; this increases the costs and decreases the strength. Furthermore, the precise shaping of the ends of the diagonal profiles for each individual space frame structure decreases possibilities for mass production and increases the costs. In the structure of the said US publication, it is not necessary to notch the chord profiles at the nodes, but also in this structure the diagonal profiles must be suitably designed for each frame structure, and one space frame structure has several different types of such individually designed diagonal profiles. Both of these factors increase the costs. The diagonal profiles are structurally such that the system is not suitable for robust structures; it is limited to relatively light frames. Furthermore, the node structure described is not advantageous in terms of strength of materials as it concentrates the forces between the diagonal profiles and the chord profiles at the nodes in a very small area and in small webs between bolts and/or in one relatively small bolt. For this reason, also, the described structure is suitable for only lightweight frame structures.

Publication DE-2 445 515 describes a space frame structure based on continuous chord profiles and having no node elements, in which structure the ends of the diagonal profiles have not been specifically shaped. In this structure, one of the chord profiles has been designed to comprise two flat flange pairs, in which case two opposite surfaces of a diagonal profile rectangular in cross-section bear against two flange surfaces of the pair of flat flanges. This chord profile, which comprises the said oblique flat flange pairs, is made up of two separate profile parts which have been hinged to each other, in which case they can be tilted to the position in which they are in the final space frame structure. The final position is locked by using self-tapping screws passing through the crosswise chord profile. Although in this system the individual design of the diagonal profiles and actual node elements are avoided, the complicated shaping of the chord profile from two parts hinged to each other results in a considerably high price. Furthermore, the node is not very advantageous in terms of strength of materials, since the diagonal profiles are connected to only one of the chord profiles and the other chord profile is secured to the first-mentioned chord profile only by using self-tapping screws. In this case the transfer of forces between the chord profiles, and from this second chord to the diagonal profiles, takes place overall through a very weak joint. This structure, also, is not suitable for forming robust frames.

It is thus an object of the invention to provide a space frame structure without node elements, in which structure all of the chord profiles are of a simple continuous and fixed profile without any bendable portions. Another object of the invention is such a space frame structure, in which it is not necessary to make any notchings or any other shapings in either chord profile at the junction points of the chord profiles crosswise to each other. Thus a third object of the invention is such a space frame structure, at the nodes of which, where the diagonal profiles are connected to either one of the chord profiles or to both chord profiles, it is necessary at most to make holes in the diagonal profile and in the chord profile to accommodate any securing members. If a securing method which does not require the use of holes is used for connecting the diagonal profiles and the chord profiles, which option is also one of the objects of the invention, it is a particular object that it is not necessary at all to perforate the diagonal profiles and the chord profiles. A fourth object of the invention is such a space frame structure, in which it is not necessary to shape the ends of the diagonal profiles in any way for their securing to the chord profiles; the diagonal profiles can merely be cut straight, or partly or entirely obliquely into suitable lengths and, when necessary, be provided with holes for possible securing members between them and the chord profiles. A fifth object of the invention is such a space frame structure, in which each diagonal profile can be secured at the nodes, where the chord profiles intersect, directly without any intermediary elements to both of these intersecting chord profiles. An additional object, due to this, is such a frame structure, in which it is not necessary to secure the intersecting upper chord profiles directly to each other and the intersecting lower chord profiles directly to each other. A sixth object of the invention is such a space frame structure, in which it is possible to form additional nodes, in addition to the junction points of the chord profiles, by placing in the frame additional diagonal profiles and/or additional chord profiles. A seventh object of the invention is such a space frame structure, in which all of the diagonal profiles are preferably of mutually the same profile. An eight object of the invention is a possibility of using in these profiles, according to the given location in the space frame, a material of the desired strength, while keeping, when necessary, the cross-sectional dimensions unchanged. A ninth object of the invention is a space frame structure in which the shapes of the profiles are open profiles and can be formed, for example, by rolling, and so as to be easily zinc coated, or alternatively hollow-core profiles. A tenth object of the invention is such a space frame structure, in which the thickness of the frame can be given the desired magnitude by using diagonal profile pieces of the desired length and by additionally arranging, in the chord grids, the sides of the grid panel of the chord profiles so as to correspond to this.

The disadvantages described above can be eliminated and the objectives defined above can be achieved by using a space frame structure according to the invention, without node elements, the structure being characterized in what is stated in the characterizing clause of Claim 1.

The most essential advantage of the invention is that in the space frame structure according to it both the chord profiles and the diagonal profiles are made of simple straight profile, from which a frame of a certain size can be assembled simply by cutting the profile into parts of the desired length and by securing the parts thus obtained, not changing their shape, to each other by using bolts, screws, welding or gluing or some other suitable method. The structure according to the invention thus has no articulations, and it is not necessary to change the shape of any profile pieces; at most, the drilling of holes for the securing members will suffice. Another advantage of the invention is that at the nodes formed by the junction points of the chord profiles it is not necessary to make any notchings, and at these points the diagonal profiles connect directly to both chord profiles, surface against surface. Thus a very strong frame is obtained, since the forces are transferred directly between the two chord profiles and the diagonal profiles.

It is a further advantage of the invention that all of the diagonal profile pieces can, when necessary, be mutually similar, in which case no assorting for purposes of transportation and assembling of the frame structure is necessary. This also enables the frame structure to be assembled rapidly and simply. In a preferred frame structure according to the invention, all the chord profiles may also be of the same profile. By using, for example, roll forming for the manufacture of the profiles, the total strength of the frame structure and/or the strength and rigidity proportions of its various points, can always be adjusted to that required by a given situation, with very small changes in the manufacture. Thus it is very easy to use a thicker or stronger steel or other material in the areas subject to the greatest stress and to take into account, for example, the fact that in a part subject to tensile stress it is often preferable to use a stronger but thinner material and in parts subject to compressive stress a thicker material with less strength, while the principal shape of the profiles will remain unchanged and the manufacturing costs very low.

Furthermore, it is an advantage of the invention that by using a structure according to the invention it is also easy to implement frames in which the first and second upper chord profiles mutually and the first and second lower chord profiles mutually form a grid pattern which is not in the conventional manner made up of squares but, for example, of rectangles, diamonds or other parallelograms. Such frame structures are advantageous in terms of strength of materials in situations in which the load is unevenly distributed and, for example, in the longitudinal direction of the frame different from that in the transverse direction. On the other hand, sometimes such a frame is desirable for architectural reasons.

The invention is described below in detail, with reference to the accompanying figures.

Figure 1 depicts generally a space frame structure according to the invention, in an axonometric representation.

Figure 2 depicts one node formed by a junction of upper chords and diagonal profiles in a space frame structure according to the invention, in the same representation as in Figure 1.

Figure 3 depicts one node formed by a junction of lower chords and diagonal profiles in a space frame structure according to the invention, in the same representation as in Figure 1.

Figure 4 depicts a top view of one embodiment of the space frame structure according to the invention, having square grid panels, in a direction perpendicular to the length and the width of the frame, as seen from direction I in Figure 1.

Figures 5A-5E depict cross-sections of other alternative chord profiles.

Figures 6A-6D depict cross-sections of other alternative diagonal profiles.

Figure 7 depicts a top view of another embodiment of the space frame structure according to the invention, having rectangular grid panels, in a direction perpendicular to the length and the width of the frame, in the same representation as in Figure 4.

Figure 8 depicts a top view of a third embodiment of the space frame structure according to the invention, having parallelogram-shaped grid panels, in a direction perpendicular to the length and width of the frame, in the same representation as in Figure 4.

The space frame structure according to the invention, without node elements, shown in the figures, comprises first upper chord profiles 1 and second upper chord profiles 2, which run crosswise relative to each other and are typically made up of continuous, i.e. unbroken profiles. The structure also comprises continuous first lower chord profiles 3 and second continuous lower chord profiles 4, which run crosswise relative to each other and are preferably made up of continuous, i.e. unbroken profiles. All of the first upper chord profiles 1 are mutually parallel and, furthermore, all of the first lower chord profiles 3 are mutually parallel, and typically these first upper chord profiles and the first lower chord profiles are also mutually parallel. Respectively, the second upper chord profiles 2 are mutually parallel and the second lower chord profiles 4 are mutually parallel, and, furthermore, these second upper chord profiles and the second lower chord profiles are typically mutually parallel. This positioning of the chord profiles can be seen most clearly in Figure 4. In the embodiment of Figure 1, the second upper chord profiles are above the first upper chord profiles and against them, and likewise the second lower chord profiles are above the first lower chord profiles and against them, as seen from direction I. In this case the distance H1 between the plane formed by the first upper chord profiles 1 and the plane formed by the first lower chord profiles 3 is equal to the distance H2 between the plane formed by the second upper chord profiles 2 and the plane formed by the second lower chord profiles 4. However, there is no obstacle to the arranging of the relative positions of these chords differently, in which case the distances H1 and H2 between the planes are of different magnitudes. In such a case, for example, the second lower chord profiles 4 would be below the first lower chord profiles 3.

When the first and second upper chord profiles are against each other, or almost against each other, and interconnected to each other by mediation of diagonal profiles, in the manner explained below, and respectively the first and second lower chord profiles are against each other, or almost against each other, and interconnected by mediation of diagonal profiles, in a manner explained below, there is formed a space frame having two chord grids, in which the effective distance between the chord grids is $H = (H1 + H2)/2$. In the embodiment described in the present application, the effective distance between the chord grids is thus $H = H1 = H2$. The first and second upper chord profiles 1, 2 together serve as one chord grid and, respectively the first and second lower chord profiles 3,4 serve as one chord grid.

In a usual situation, nodes 6 and 7 of the space frame structure are formed from the junctions of the first and second upper chord profiles 1, 2, as well as from the junctions of the first and second lower chord profiles 3, 4, by connecting at these points diagonal profiles 5 to the chord profiles. These diagonal profiles 5 always run from a node 7 of the lower chord profiles to a node 6 of the upper chord profiles, as can be seen clearly in Figure 4. Typically, four diagonal profiles depart pyramidally and symmetrically from each node 6, 7 formed by the junctions, the corner points of each pyramid being nodes in the upper or lower chord grid, and the tip of the pyramid being a node in the opposite, either lower or upper, chord grid. With respect to the number of these diagonal profiles it is possible to make normal alterations known in the context of space frame structures, i.e. some of the diagonal profiles may be omitted, in which case the frame becomes somewhat lighter in weight, although at the expense of the bearing capacity. Also, in either chord grid the chord profile frequency can be altered in a manner generally known in frame structures, but in this case the apex angle 2β of the chord profile cross-section, discussed below, and the L-angle 2α of the diagonal profile cross-section must, of course, be adjusted to correspond to this space frame arrangement.

According to the invention, both the first and the second upper chord profiles 1, 2, as well as the first and the second lower chord profiles 3, 4, comprise each two continuous flat flanges which in cross-section form mutually a V-angle, or an apex angle 2β. In other words, all the chord profiles comprise each two flat flanges unbroken in the longitudinal orientation of the profile, the apex angle between the flanges in their cross section being in all chord profiles the same 2β, as can clearly be seen in Figures 2 and 3. In the embodiment of Figures 2 and 3, the inner surfaces 8 and outer surfaces 9 of each flat flange 11 are mutually parallel and thus form an apex angle 2β. In this case the diagonal profiles can, in accordance with the invention, be connected equally well to the outer surfaces 9 or the inner surfaces 8 of these flat flanges, as shown in the figures. It is also possible to use flat flanges 11 in which only the outer surface 9 forms the said apex angle 2β, but in such a case the diagonal profiles are connected at the nodes 6 and 7 only against the outer surfaces of both the first and second chord profiles. Such a design is usable if the chord profiles are formed as hollow-core profiles and not as open profiles as in the preferred embodiment shown in the figures. In other respects the chord profiles may be of any type, the only limitation deriving from the fact that there must be room for the ends of the diagonal profiles 5 to settle against these flat flanges 11. All the chord profiles may in themselves be cross-sectionally different, as long as they have the said flat flanges, but in terms of installation and machine shop techniques the preferable system is that all of the chord profiles are of the same profile type in their cross-sectional shape, and most preferably of precisely the same profile. In terms of strength of materials, on the other hand, it is most preferable to use in the lower chord profiles a material as strong as possible, since a high tensile stress prevails in them. In the upper chord profiles it is possible to use a lower-strength material, which is less expensive. When a frame structure according to the invention is used, these facts of strength of material can be taken into account, i.e. the different chord profiles may be manufactured from materials of different strengths and/or different thicknesses, while their shape can be maintained the same. Maintaining the shape either completely the same or changing it only with respect to the material thickness is advantageous in terms of manufacturing technology, since, for example, in roll forming machines these said alternatives can be made by using the same tools; at the most, adjustment of their settings may be needed before continuing the production.

According to the invention, the diagonal profiles 5 comprise each at least two continuous side surfaces 12, which in the cross-section form together an L-angle, or a spread angle, 2α. Thus in the preferred embodiment depicted in Figures 2 and 3, the diagonal profiles 5 are in the main L-shaped, the outer surfaces 12a, 12b of their L-branches forming in the cross-section the said L-angle 2α. When such an L-profile is used, the chord profiles can be secured to this diagonal profile 5, and in particular to its side surfaces 12, at the outer surfaces 9 and inner surfaces 8 of the flat flanges 11. If it is desired to use an alternative in which the diagonal profiles must be connected to the chord profiles only at the outer surfaces 9 of the flat flanges 11 of the chord profiles, it is necessary to use a diagonal profile which comprises two opposite L-shaped sections in which two adjacent side surfaces always form between their branches the above-mentioned spread angle 2α. The cross-sectional shape of such a diagonal profile is mainly a parallelogram, tetrahedron or the like, having four flat continuous side surfaces, the two spread angles 2α, formed each by two of the surfaces, being equal, in which case two adjacent flat surfaces at one node 6, 7 function in contact with the flat flange 11 of the chord profiles. Such a cross-sectional shape of a diagonal profile is shown in Figure 6D. The diagonal profiles may otherwise have any cross-sectional shape, as long as they have the number, according to the embodiment, of continuous side surfaces 12, i.e. at least two continuous side surfaces, the spread angle between them being proportioned to the apex angle between the flat flanges 11 of the chord profiles in such a manner that the flat contact, described in greater detail below, is formed between these side surfaces and the outer surfaces and/or inner surfaces of the flat flanges. It is, of course, possible to use different diagonal profiles at different points, as long as they have the said side surfaces, but in terms of machine shop and installation techniques it is preferable that all of the diagonal profiles are, in their cross-sectional shape, of the same profile type, and most preferably of precisely the same profile. In the manufacture of diagonal profiles according to the invention it is possible to apply the same alterations of material thickness and strength as were described above in connection with the chord profiles, with the same advantages. Thus in diagonal profiles subjected to compressive stress it is preferable to use a relatively thick material. When roll forming is used in the manufacture of the profiles, it is easy to alter the thickness and strength of the material, since it does not cause a need to replace the tools; most often the changing of the setting values will suffice before production is continued.

In particular, in accordance with the invention the apex angle, or V-angle, 2β between the flat flanges of the chord profiles and the spread angle, or L-angle, 2α between the side surfaces 12 of the diagonal profiles have been proportioned to each other so that at nodes 6 the continuous side surfaces 12 of the diagonal profiles 5 settle against the continuous flat flanges 11 of both the first and the second upper chord profiles 1, 2, and likewise the continuous side surfaces 12 of a diagonal profile settle against the continuous flat flanges 11 of the first and the second lower chord profiles 3, 4. To elucidate the matter, in Figures 2 and 3 the profiles have been drawn as being transparent as regards the foremost diagonal profiles 5, and the contact surfaces between the diagonal profiles and the chord profiles have been hatched obliquely. Thus, at the node 6 depicted in Figure 2 the first side surfaces 12a of the diagonal profiles settle against the outer surfaces 9 of the first upper chord profile 1, and the second side surfaces 12b settle against the inner surfaces 8 of the flat flange 11 of the second upper chord profile 2. Likewise, at the node 7 depicted in Figure 3, the first side surfaces 12a of the diagonal profiles 5 settle against the inner surfaces 8 of the first lower chord profile 3, and the second side surfaces 12b against the outer surfaces 9 of the second lower chord profile 4. It is in particular emphasized in this connection that between the side surfaces of the diagonal profiles and the flat flanges of the chord profiles there is a contact surface at which these profiles settle surface against surface in the area indicated by the hatching, and that one diagonal profile is in this manner in contact with both chord profiles at the node concerned. The diagonal profile thus also ties the intersecting chord profiles to each other, and no other fasteners are required between the chord profiles. Within these contact areas the diagonal profiles are secured to the chord profiles by means of fasteners 20. The fasteners 20 may be rivets, bolts, screws or other corresponding fasteners, or the joint can be made by welding or gluing or by some other corresponding securing method. What is essential is, however, the surface contact described above, the contact producing a very rigid and strong node between the chord profiles and the diagonal profiles, and thereby a very strong and rigid space frame structure, regardless of the securing method.

When the preferred profile shape depicted in Figures 2 and 3 is used, together with a general space frame structure in which the distance H0 between the chord grids is equal to the distance H1 between the first upper and lower chord profiles and to the distance H2 between the second upper and lower chord profiles, i.e. $H = H1 = H2$, for example the values shown in the following Table 1 are obtained for the apex angle 2β between the flat flanges 11 of the chord profiles 1, 2; 3, 4, and for the spread angle 2α between the side surfaces 12 of the diagonal profiles 5. Table 1 also shows some theoretical lengths P (measured from the web of one chord profile to the web of another chord profile) for the diagonal braces 5 and lengths K1-K4 (measured from the center point of one node to the center point of another node) for the sides of the grid panels formed by chord profiles 1 and 2; 3 and 4. In this case, as is usual, all of the grid panels are of equal size, and their sides are of equal length, i.e. $K = K1 = K2 = K3 = K4$, in which case the grid panel formed both by the lower cords and by the upper cords is thus a square. This embodiment and the square grid panel can be seen in Figure 4:

Table 1 (grid panel is a square)

Apex angle (2β) of chord profiles	120°	102°	90°	71°	60°	40°
L-angle (2α) of diagonal profiles	41°	53°	60°	71°	83°	83°
Theoretical length (P) of diagonals	2.6H	2.0H	1.7H	1.4H	1.3H	1.1H
Side length (K1-K4) of grid panel	3.5H	2.5H	2.0H	1.4H	1.2H	0.7H

In a general form, in a frame according to the above the spread angle between the side surfaces 12 of the diagonal profiles can be calculated from the following equation: $\sin \alpha = (\cos \beta) / \sqrt{2}$, where angle β is one-half of the apex angle 2β of the chord profiles, and angle α is one-half of the spread angle 2α between the side surfaces. It is clear that this dependence applies only to the frame design described above, which is a so-called square-on-square frame. In this embodiment, all of the diagonal profiles are also equally long. If some other frame form is used, the dependence between angles α and β is, of course, in accordance with some other equation. However, regardless of the form of the frame, the apex angle 2β formed by the flat flanges 11 of the chord profiles is typically within the range 120°-40°, and preferably in the order of 90°-60°. If in this case the cross-sectional shape is a symmetrical truncated V-shape, the inside fold angles of the profile shape are equal, i.e. 90+β, as shown in Figures 2 and 3. Respectively, the spread angle 2α between the side surfaces 12 of the diagonal profiles 5 is typically within a range of approx. 40°-90°, preferably in the order of 60°-76°. Within angle ranges such as these, even open profiles, as well as hollow-core profiles, rigid against both folding and buckling are obtained. These values, defined above, for the apex angle 2β and for the spread angle 2α are thus independent of the cross-sectional shape of the profile.

Below, the implementation of the frame structure according to the invention in a frame of a different shape is depicted with the help of Table 2. In this frame, the distance K2 between the second upper chord profiles is greater than the distance K1 between the first upper chord profiles, and respectively the distance K4 between the second lower chord profiles is greater than the distance K3 between the first lower chord profiles, but nevertheless the chord profiles are at right angles to each other. The grid panels formed by the lower chords are in this case of the same shape and the same size as the grid panels formed by the upper chords, i.e. K1 = K3 < K2 = K4, the grid panels thus being rectangles.

Table 2 (grid panel is a rectangle)

Apex angles ($2\beta_2/2\beta_1$) of chord profiles	120°/90°	90°/60°	71°/60°	60°/45°
L-angle (2α) of diagonal profiles	52°	69°	73°	79°
Theoretical length (P) of diagonals	2.2H	1.5H	1.4H	1.2H
Side lengths (K1,K3/K2,K4) of grid panel	2.0H/3.5H	1.2H/2.0H	1.2H/1.4H	0.8H/1.2H

As can be seen in Table 2, the apex angles 2β of the chord profiles and the apex angles 2α of the diagonal profiles are within the same range as those described above, although in this case the apex angles $2\beta_2$ of the second upper and lower chord profiles 2, 4 are not equal to the apex angles $2\beta_1$ of the first upper and lower chord profiles. However, in this case, also, the spread angles 2α of all of the diagonal profiles 5 are equal, and all of the diagonal profiles are equal in length. This frame form and its grid panels can be seen in Figure 7.

Next, the implementation of the frame structure according to the invention in a third frame type is described with the help of Table 3. The most essential feature in it is that the chord profiles are not perpendicular to one another; in the chord grids they form mutually grid angles φ_2=75° and φ_1=105°, and thus the grid panel is either a diamond or more commonly a parallelogram, in which the opposite angles are thus equal.

Table 3 shows a more common situation, in which the proportions of the side lengths of the grid panels are generally K1 = K3 < K2 = K4, in which case the lower chords together and the upper chords together thus form parallelogram panels.

Table 3 (grid panel is a parallelogram in which φ_1=105° and φ_2=75°)

Apex angle ($2\beta_2/2\beta_1$) of chord profiles	120°/90°	90°/60°	71°/60°	60°/45°
L-angle (2α) of diagonal profiles	45°/59°	59°/79°	62°/84°	67°/91°
Theoretical length (P) of diagonals	2.1H/2.5H	1.5H/1.7H	1.3H/1.5H	1.2H/1.3H
Side length (K1,K3/K2,K4) of grid panel	2.1H/3.6H	1.2H/2.1H	1.2H/1.5H	0.9H/1.2H

As can be seen in Table 3, the apex angles 2β of the chord profiles and the apex angles 2α of the diagonal profiles are within the same range as was described above, although in this case the apex angles $2\beta_2$ of the second upper and lower chord profiles 2, 4 are not equal to the apex angles $2\beta_1$ of the first upper and lower chord profiles 1, 3. In this case, however, the spread angles $2\alpha_1$ of the first diagonal profiles 5, which connect nodes 6, 7 within the area of the larger angle φ_1 of the grid panel, are smaller than the spread angles $2\alpha_2$ of the second diagonal profiles 5, which connect the nodes 6, 7 within the area of the smaller angle φ_2 of the grid panel. The theoretical length P_1 of the first diagonal profiles is in this case smaller than the theoretical length P_2 of the second diagonal profiles. This frame form and its grid panels can be seen in Figure 8.

As is evident from the tables, by means of the apex angle 2β between the flat flanges 11 of the chord profiles and the spread angle 2α between the side surfaces 12 of the diagonal profiles it is possible to adjust the inclination of the diagonal profiles and thereby the distance H between the upper chord 1,2 and the lower chord 3,4, as well as the length K of the side of the grid panel, to the desired magnitudes. When the apex angle 2β of the flat flanges of the chord profiles is maintained constant and the spread angle 2α of the side surfaces of the diagonal profiles is maintained constant, the distance H between the upper chord and the lower chord can be increased or decreased while the length of the side of the grid panels of the upper chord and the lower chord is lengthened in the same proportion. Thus, by using the space frame structure according to the invention, a frame having the desired thickness H and the desired frequency of diagonals can be obtained in each given case.

Preferably the apex angles 2β of the first and second upper chord profiles 1, 2 open mutually in the same direction and preferably towards the interior of the space frame. Respectively, the apex angles 2β of the first and second lower chord profiles 3, 4 open mutually in the same direction, towards the interior of the space frame. In this case, the edges 13 of the flat flanges 11 of the second upper chord profiles 2 will advantageously settle against the ridge of the shape of the first upper chord profiles 1 or, in the embodiment of Figures 1-3, against the web 14 of the truncated V-shape, and, in a respective manner, the edges 13 of the flat flanges 11 of the first lower chord profiles 3 will settle against the ridge of the shape of the second lower chord profiles 4 or, respectively, against the web 14 of the truncated V-shape, as shown in Figures 1-3. Since the first and the second profiles may be mutually in a different order, the contact order referred to above may be reverse to what has been described. This will not change the principles described above in the present application. In principle the apex angles of the chord profiles may also open outwards from the space frame, but in such a case the diagonal profiles will have to intersect between the chords, which may cause problems.

Sufficient room for the ends of the diagonal profiles 5 will be obtained between the flat flanges 11 of the chord profiles and a sufficient surface area will be obtained for the flat contacts between the diagonal profiles and the flat flanges of the chord profiles if the chord profile 1-4 used has the cross-sectional shape of a truncated V and the widths W1 of the flat flanges 11 are typically within a range of one-third of to equal to the width W2 of the web 14 of the truncated V-shape. Preferably these flat flange widths W1 are approx. one-half of the web width W2. Thus the chord profiles may have a cross-sectional shape either completely V-shaped, as shown in Figure 5A, or they may be open profiles having the shape of a truncated V, as shown in Figures 2 and 3. This in the main V-shaped design has also the advantage that at the nodes 6, 7 formed at the junction points of the chord profiles the first and second chord profiles, and in particular their flat flanges 11, can be brought close to each other, in which case the strengths and rigidities of the chord grids will be the same in the orientations of both the first and the second chord profiles, and the joint between the first and the second chord profiles will be rigid. If the chord profiles are entirely or in part made as hollow-core profiles, they may also be A-shaped, trapezoidal, triangular, which are also in principle V-shaped profiles, or hexagonal or the like in their cross-section, as shown in Figures 5B-5E. A hexagonal shape which has two opposite apex angles 2β between the flat flanges is suitable for use in frames which have more than two chord grids, but it may, of course, also be used in space frames with two chord grids, which are discussed in greater detail in the present application.

The diagonal profiles 5 may, as may the chord profiles, also be hollow-core profiles either entirely or in part. In such a case the cross-sectional shape of the diagonal profiles is A-shaped, trapezoidal, triangular or a parallelipipedon or the like, as shown in Figures 6A-6D. However, it is preferable to make also the diagonal profiles as open profiles, in which case they are easy to galvanize, e.g. to hot galvanize. A sharp-tipped cross-sectional shape of the diagonal profile, such as shown in Figures 2, 3, 6A and 6C-6D, is advantageous, since in such a case the contact surface area of the diagonal profile and the chord profiles at their nodes, in particular at nodes 6, 7 formed at the junction points of the chord profiles, is maximal. As is evident from the tables above, the apex angle 2β between the flat flanges 11 of the chord profiles 1, 2; 3,4 may be precisely the same as the angle 2α between the side surfaces 12 of the diagonal profiles 5. In this case all the chord profiles and diagonal profiles may, if so desired, be of a profile exactly the same, at least in shape.

The chord profiles and diagonal profiles according to the invention are preferably open profiles, such as shown in Figures 2, 3 and 5A, since such profile shapes can be formed, for example, by the roll-forming method, in which case profiles having the desired cross-sectional dimensions and the required lengths can be manufactured flexibly. The advantages gained by using this manufacturing method were already described earlier in the present application. The wall thicknesses may vary typically within the range 4-12 mm but, depending on the apparatus and the purpose of use, they may be even smaller than the said 4 mm or greater than the said 12 mm. In a space frame structure according to the invention the thickness H of the frame is the frame span length D5 and/or D4 divided by a number of 10-30. Typically the frame thickness H is the span length divided by a number of 15-20 but, when necessary, these values can be deviated from.

In a space frame structure according to the invention it is easy to arrange additional nodes 21, 22, for example in the area of the frame edges, to stiffen the space frame. This is done by securing to the flat flange 11 of an upper chord profile 1 or 2 and to the flat flange 11 of a lower chord profile 3 or 4 additional diagonals 15a between them at points which are between the nodes 6, 7 formed by the junction points of the chord profiles. Figure 1 shows one such additional diagonal 15a, but it is clear that in a practical situation a plurality of such diagonals are provided at each edge of the space frame structure, for example, within each distance between the nodes 6,7 formed by the chord profile junctions. These additional diagonals 15a may be inclined alternately in different directions. These additional diagonals may have the same length as the other diagonal profiles, or they may designed to be of a different length, for example, of the magnitude of the perpendicular distance between the first upper and lower chords. At those points of the space frame structure edges at which the chord profiles end there are in most cases formed nodes even if they are not dimensionally chord profile junctions. However, in most cases the edge of the space frame is arranged at the point at which there will be a node 6 formed by upper chord profiles 1 and 2 or a node 7 formed by lower chord profiles 3 and 4. In such a case the diagonals belonging at this point are in any case brought to this point, and so they serve as nodes. At the intersection line of the lower chord profiles or, respectively, upper chord profiles and the space frame edge, which is at the distance of half the length of a side of a grid panel from the nodes formed by the chord profile junctions, it is possible to form, by using diagonal profiles of a differing length or diagonal profiles 15b having a length corresponding to the other diagonal profiles, additional nodes 25 in the manner described above. This first-mentioned design is not shown in the figures of the application, but the latter design is shown in Figure 1. In it, additional diagonal profiles 15b, having the length of the other diagonal profiles, form additional nodes 22 and 25 in the lower chord profiles and, respectively, upper chord profiles, and in the latter at the frame edge.

The space frame structure without node elements, in accordance with the invention, can with relative ease be also designed as a raised or pre-cambered frame. This is done by making at least some of the first or second lower chord profiles 3 or 4 of at least two profile elements. Figure 4 shows an embodiment in which the two lower chord profiles 3 and 4 are each made of three profile elements 23a-23c and 24a-24c, in which case the total combined length D1+D2+D3 of the profile elements 23a-23c of the first lower chord profile 3 is smaller than the length D4 of the completed frame structure in the orientation concerned, and likewise the total combined length D1+D2+D3 of the three profile elements 24a-24c of the second lower chord profile 4 is smaller than the length D5 of the completed frame structure in this orientation. Thus there will be small gaps 17 between the profile elements 23a-c, 24a-c at the assembling stage of the frame structure. At the end of the assembling stage, these gaps 17 are reduced or entirely closed by using tightening means, not shown in the figures, which cross the gaps, whereupon tensile stress is produced on the lower-chord side of the frame structure, whereupon the unloaded space frame structure will rise and become slightly cambered towards the upper chord 1, 2. When, thereafter, the space frame structure is loaded from above, from direction I in Figure 1, in the normal manner, the shape of a correctly dimensioned and pre-cambered space frame structure against the loading force in a perpendicular direction will be substantially flat. However, often it is not necessary to design the space frame so as to be pre-cambered, and so it is possible to use continuous, or in very large frames conventionally extended, chord profiles which extend over the entire lengths D4, D5 of the frame. If pre-cambering is used, the lengths of the profile elements 23 24 can be selected expediently and independently of the distances between the nodes.

Claims

1. A space frame structure without node elements, the structure comprising first (1) and second (2) continuous upper chord profiles running crosswise relative to each other and first (3) and second (4) continuous lower chord profiles running crosswise relative to each other, as well as diagonal profiles (5) which connect at least some of the junction points (6) of the upper chord profiles to at least some of the junction points (7) of the lower chord profiles, whereby space frame structure nodes are formed, at which the diagonal profiles are by their continuous side surfaces connected to at least one of the chord profiles, **characterized** in that both the first and the second upper chord profiles (1, 2), as well as both the first and the second lower chord profiles (3, 4) comprise each two continuous flat flanges (11), which in cross-section form between them an apex angle (2β), that the diagonal profiles (5) comprise at least two continuous side surfaces (12) which in cross-section mutually form a spread angle (2α), and that the diagonal profiles (5) are at the nodes (6, 7) secured directly by their continuous side surfaces (12) to both the first and the second upper chord profiles (1, 2) and, respectively, to both the first and the second lower chord profiles (3, 4), to their continuous flat flanges (11).

2. A space frame structure according to Claim 1, **characterized** in that at the nodes (6, 7) the side surfaces (12) of the diagonal profiles (5) and the flat flanges (11) of the first and the second chord profiles (1, 2 or 3, 4) rest surface against surface, that the side surfaces (12) of the diagonal profiles are outer surfaces of a spread angle (2α) and settle against either the inner flange surface (8) or the outer flange surface (9) of the apex angle (2β) of the chord profiles.

3. A space frame structure according to Claim 1 or 2, **characterized** in that the chord profiles (1, 2; 3, 4) are preferably all of a profile cross-sectionally of the same type, that in

all the chord profiles the apex angle (2β) between the flat flanges (11) is equal, typically within the range 120°-40°, preferably in the order of 90°-60°, and that the cross-sectional shape of the chord profiles has preferably in the main a V-shape, and typically a truncated V-shape, in which the inner fold angles (10) are equal ($90+\beta$).

4. A space frame structure according to Claim 3, **characterized** in that in the chord profiles (1, 2; 3, 4) the widths (W1) of the flat flanges (11) of the truncated V-shape of the cross-section are 1/3 - 1 times the width (W2) of the web (14) of the truncated V-shape, and preferably these widths are approximately one-half the width of the said web width.

5. A space frame structure according to Claim 1, **characterized** in that the apex angles (2β) of the first and the second upper chord profiles (1, 2) open mutually in the same direction, either outwards from the space frame or, preferably, towards the interior of the space frame, and that, respectively, the apex angles (2β) of the first and the second lower chord profiles (3, 4) open mutually in the same direction, either outwards from the space frame or, preferably, towards the interior of the space frame, the edges (13) of the flat flanges (11) of the first or second upper and, respectively, lower chord profiles settling against the ridge of the V-shape or against the web (14) of the truncated V-shape of the second or first upper and, respectively, lower chord profiles.

6. A space frame structure according to Claim 1 or 5, **characterized** in that the first upper chord profiles (1) and the first lower chord profiles (3) mutually, and likewise the second upper chord profiles (2) and the second lower chord profiles (4) mutually, are parallel, and that the distance (H1) between the planes formed by the first upper chord profiles and by the first lower chord profiles is equal to the distance (H2) between the planes formed by the second upper chord profiles

and the second lower chord profiles.

7. A space frame structure according to Claim 1 or 6, **characterized** in that the mutual distances (K1, K2) between the first and between the second upper chord profiles (1, 2) are equal to the mutual distances (K3, K4) between the first and between the second lower chord profiles (3, 4), in which case the shape of the grid panel is at least approximately square.

8. A space frame structure according to Claim 1 or 6, **characterized** in that the distances (K1) between the first upper chord profiles and, respectively, the distances (K3) between the first lower chord profiles (3) are of a magnitude different from that of the distances (K2) between the second upper chord profiles (2) and, respectively, the distances (K4) between the second lower chord profiles (4), and/or the upper chord profiles (1, 2) together and the lower chord profiles (3, 4) together form grid angles (φ_1, φ_2) deviating from a right angle, the shape of the grid panel thus being a rectangle, diamond or parallelogram.

9. A space frame structure according to Claim 1, **characterized** in that all of the diagonal profiles (5) are of a profile of the same type in cross-section, preferably of the same profile, the cross-section of which comprises at least one approximately L-shaped portion in which the spread angle (2α) between the branches forming the side surfaces (12) is typically within a range of approx. 40°-90°, preferably in the order of 60°-76°.

10. A space frame structure according to Claim 1 or 9, **characterized** in that the diagonal profiles (5) are in the main L-shaped or, alternatively, U-shaped in cross-section, the cross-sectional shape comprising one or, respectively, two L-shaped portions coming into contact by two or, respectively, three side surfaces (12) with the flat flanges (11) of the chord

profiles (1, 2; 3, 4).

11. A space frame structure according to Claim 1 or 7, **characterized** in that the spread angle (2α) between the side surfaces (12) of the diagonal profiles (5) is obtained from the following equation: $\sin \alpha = 1/\sqrt{2} * \cos \beta$, where the angle (β) is one-half of the V-apex angle of the chord profiles.

12. A space frame structure according to Claim 1, **characterized** in that the chord profiles (1, 2; 3, 4) are, at least in the main, open profiles, and that the diagonal profiles (5) are at least in the main open profiles, both of the profiles being manufactured from a sheet or from continuous sheet by roll forming, and that the upper chord profiles (1, 2) have been manufactured from a material having a strength different from that of the lower chord profiles (3, 4), and the diagonal profiles (5) from a material having a strength different from that of either the upper chord profiles or the lower chord profiles, or both.

13. A space frame structure according to Claim 6, **characterized** in that in each diagonal profile (5) its first continuous side surface (12a) is located against the surface of the flat flanges of the first upper chord profiles (1) and against the surface of the flat flanges of the first lower chord profiles (3) and its second continuous side surface (12b) is located against the surface of the flat flanges of the second upper chord profiles (2) and against the surface of the flat flanges of the second lower chord profiles (4).

14. A space frame structure according to Claim 1, **characterized** in that additional nodes (21, 22, 25) are arranged in the space frame by securing to the flat flanges (11) of the upper chord profiles (1 or 2) and to the flat flanges (11) of the lower chord profiles (3 or 4) additional diagonal profiles (15a, 15b) between them at points which are between or outside

the nodes formed by the said junction points (6, 7) of the chord profiles.

15. A space frame structure according to Claim 1, **characterized** in that the chord profiles (1, 2; 3, 4) and/or the diagonal profiles (5) are entirely or in part hollow-core profiles.

16. A space frame structure according to Claim 1, **characterized** in that the side surfaces (12) of the diagonal profiles (5) are secured to the flat flanges (11) of the chord profiles (1, 2; 3, 4) within the area of the contact surface between them by using rivets, bolts, welding, gluing, or some other corresponding fastener or jointing method.

17. A space frame structure according to Claim 1, **characterized** in that in the frame structure each of the first and/or second lower chord profiles (3 and/or 4) is formed from at least two profile elements (23a-c, 24 a-c), the total combined length (D1+D2+D3) of which is smaller than the length of the completed frame structure (D4, D5) in the same direction, there being between the profile elements gaps (17), and that these gaps (17) are closed or reduced by tightening after the assembling of the space frame structure in order to produce a cambered frame structure.

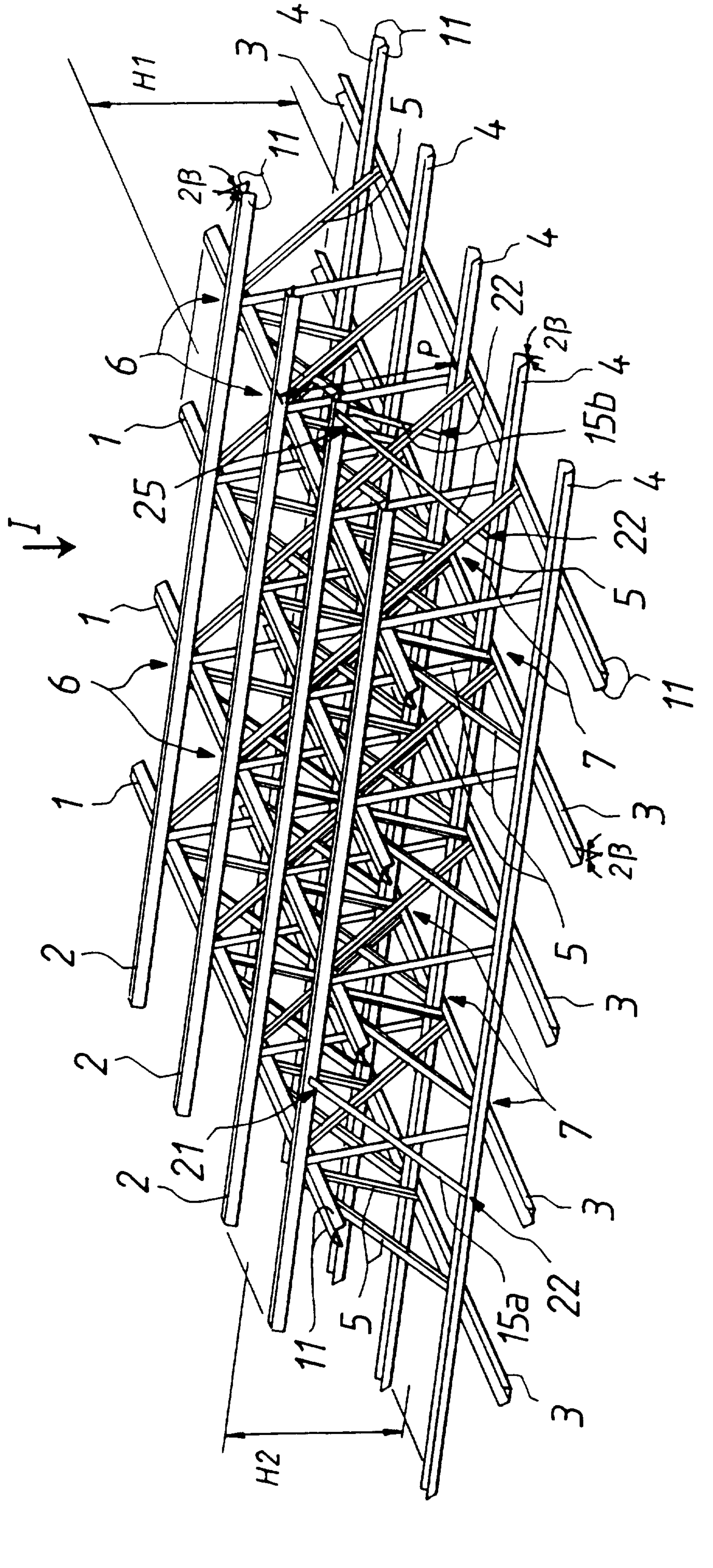


Fig.1

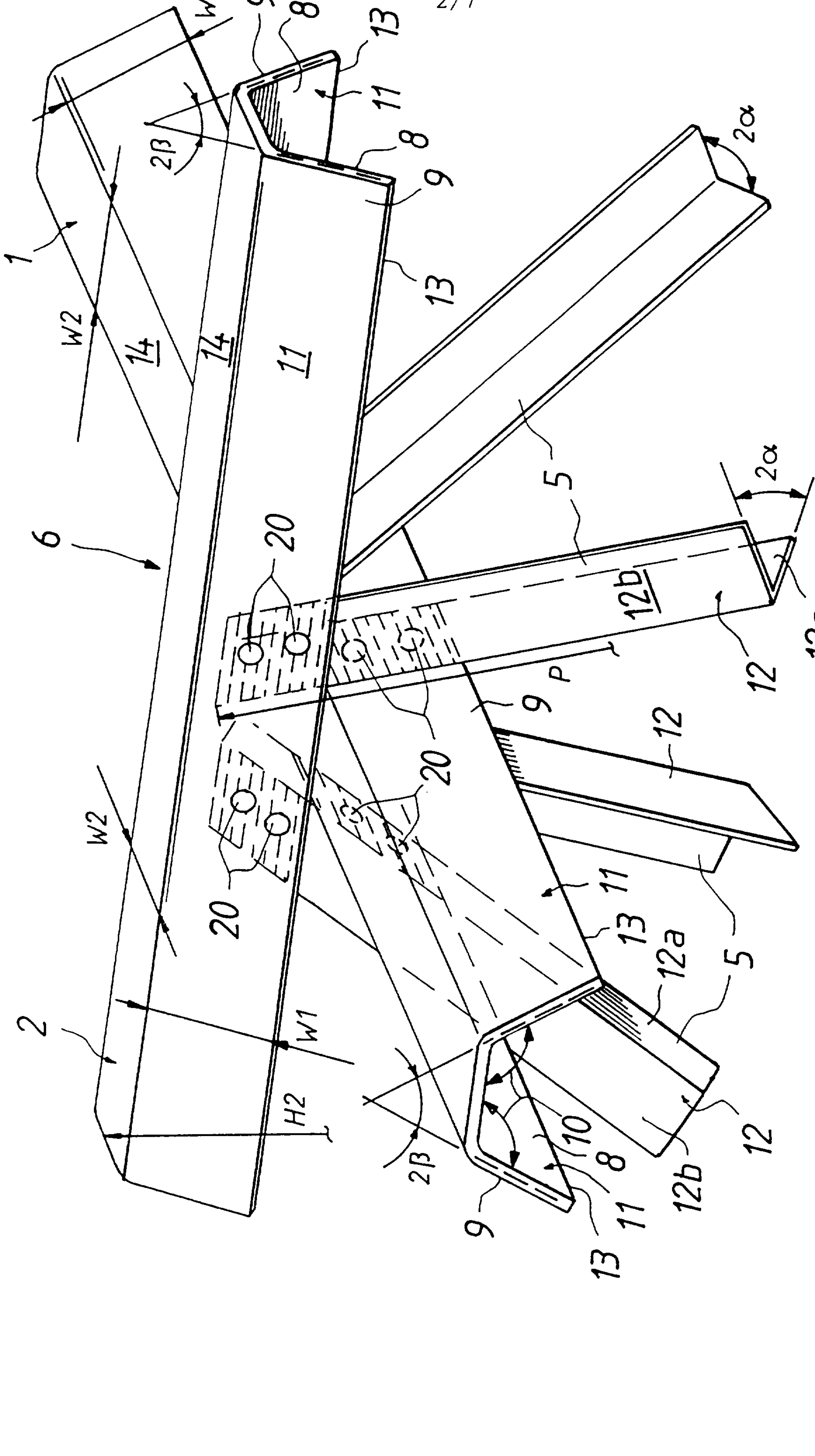
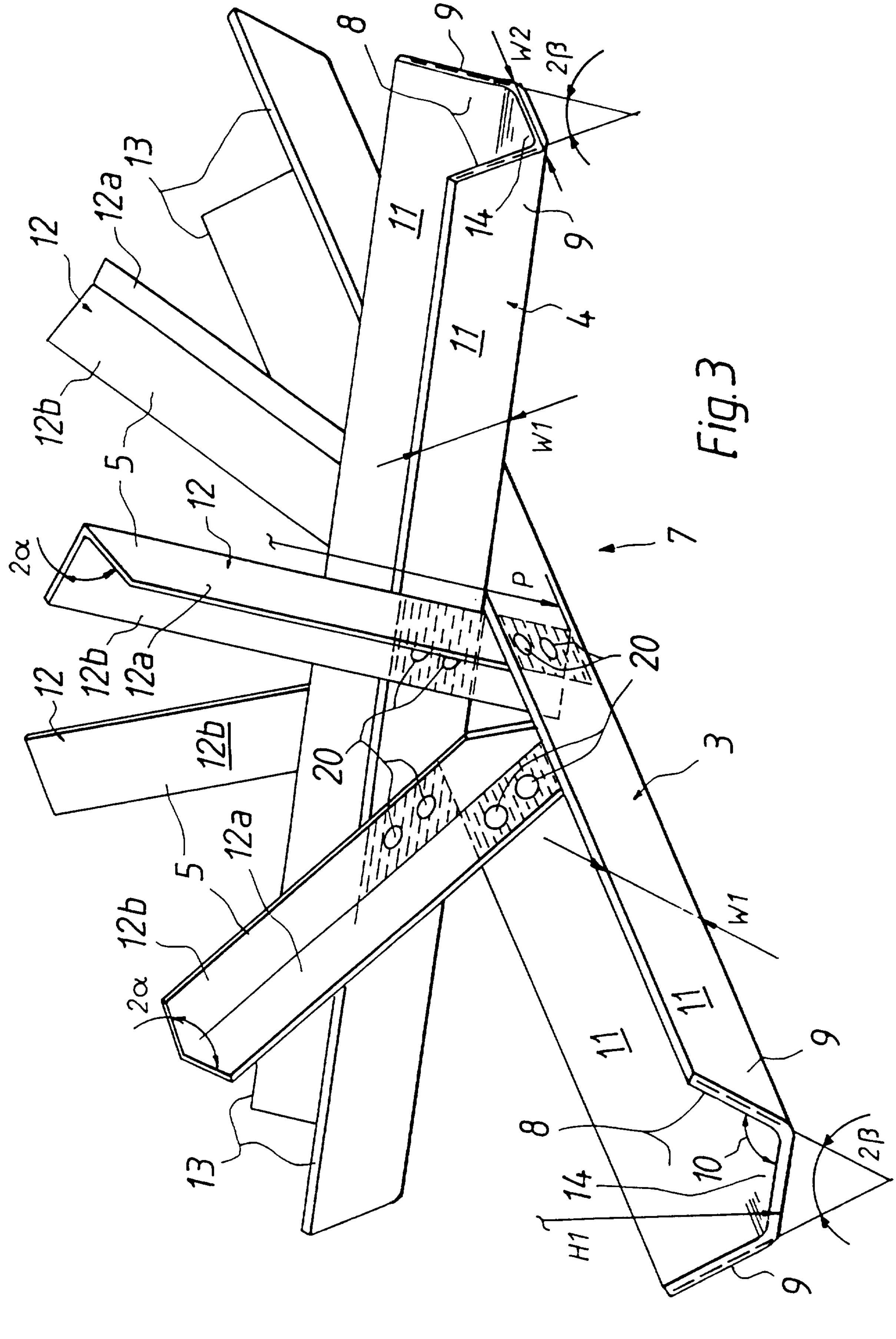


Fig.2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8
13
12a
12
12b
5
11
14
4
W1
2α
12b
12a
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P
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L
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12b
2α
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9
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10
13
14
H1
2β
9

Fig.3

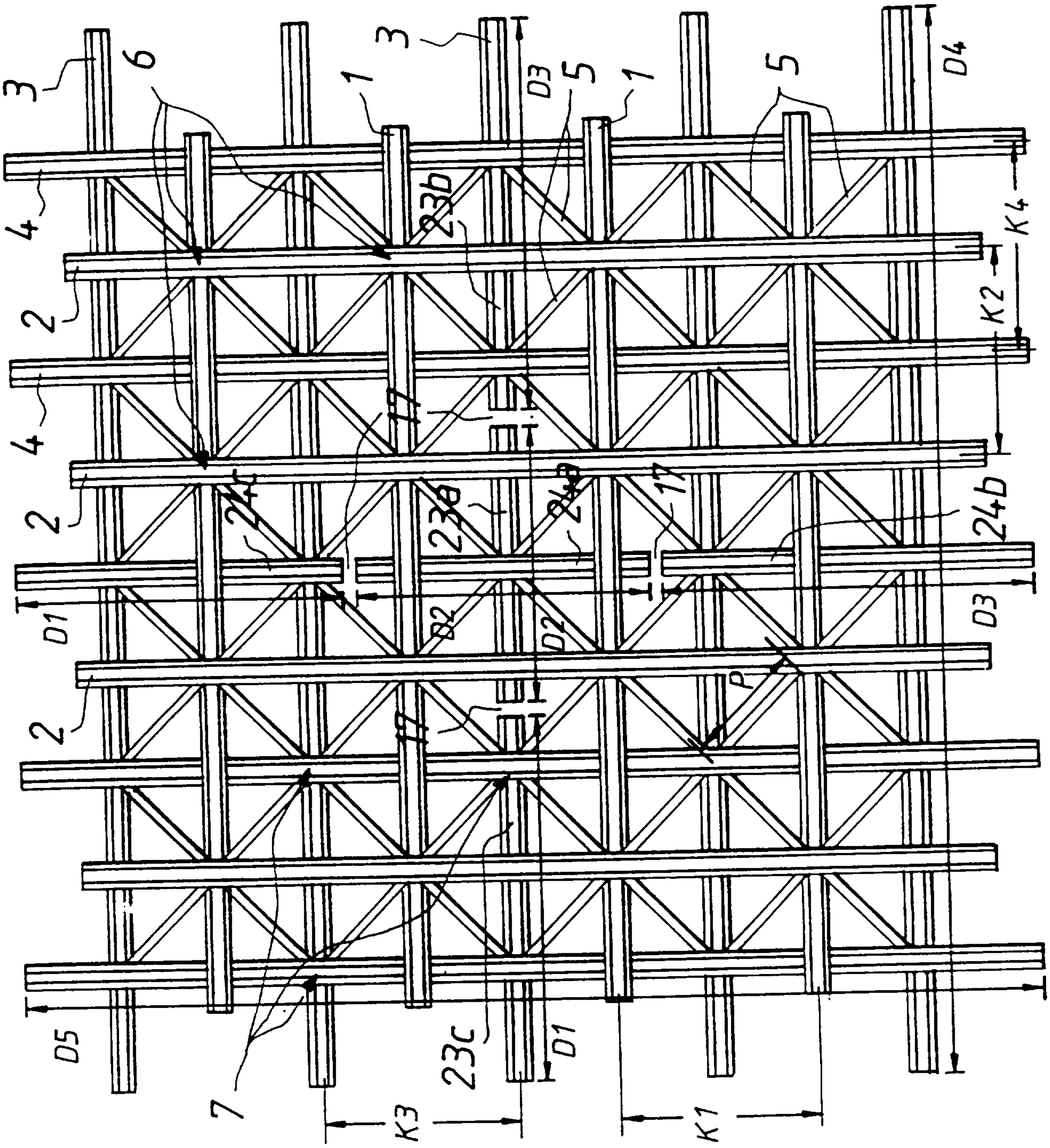


Fig.4

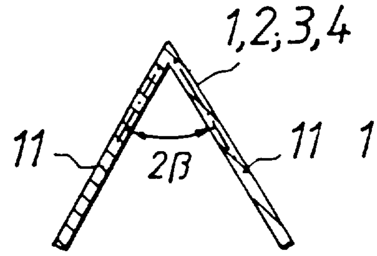


Fig.5A

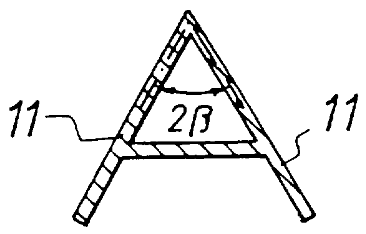


Fig.5B

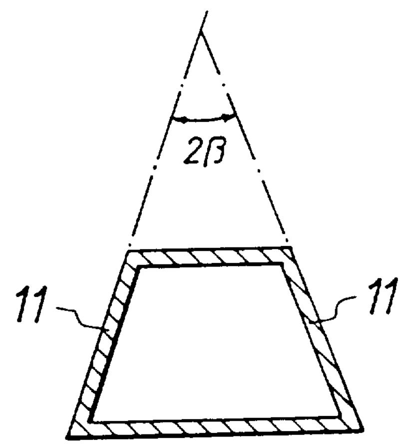


Fig.5C

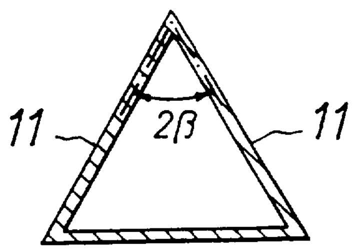


Fig.5D

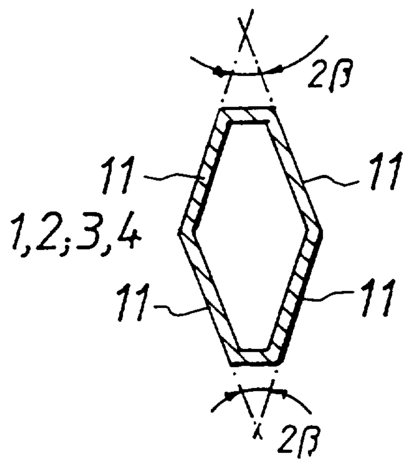
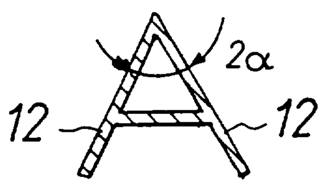


Fig.5E

Fig.6A



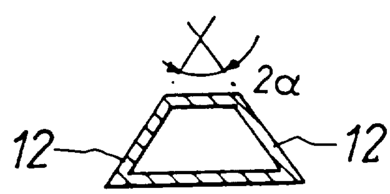


Fig.6B

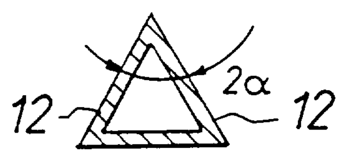


Fig. 6C

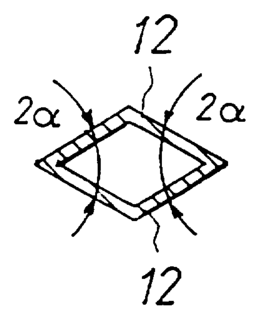


Fig.6D

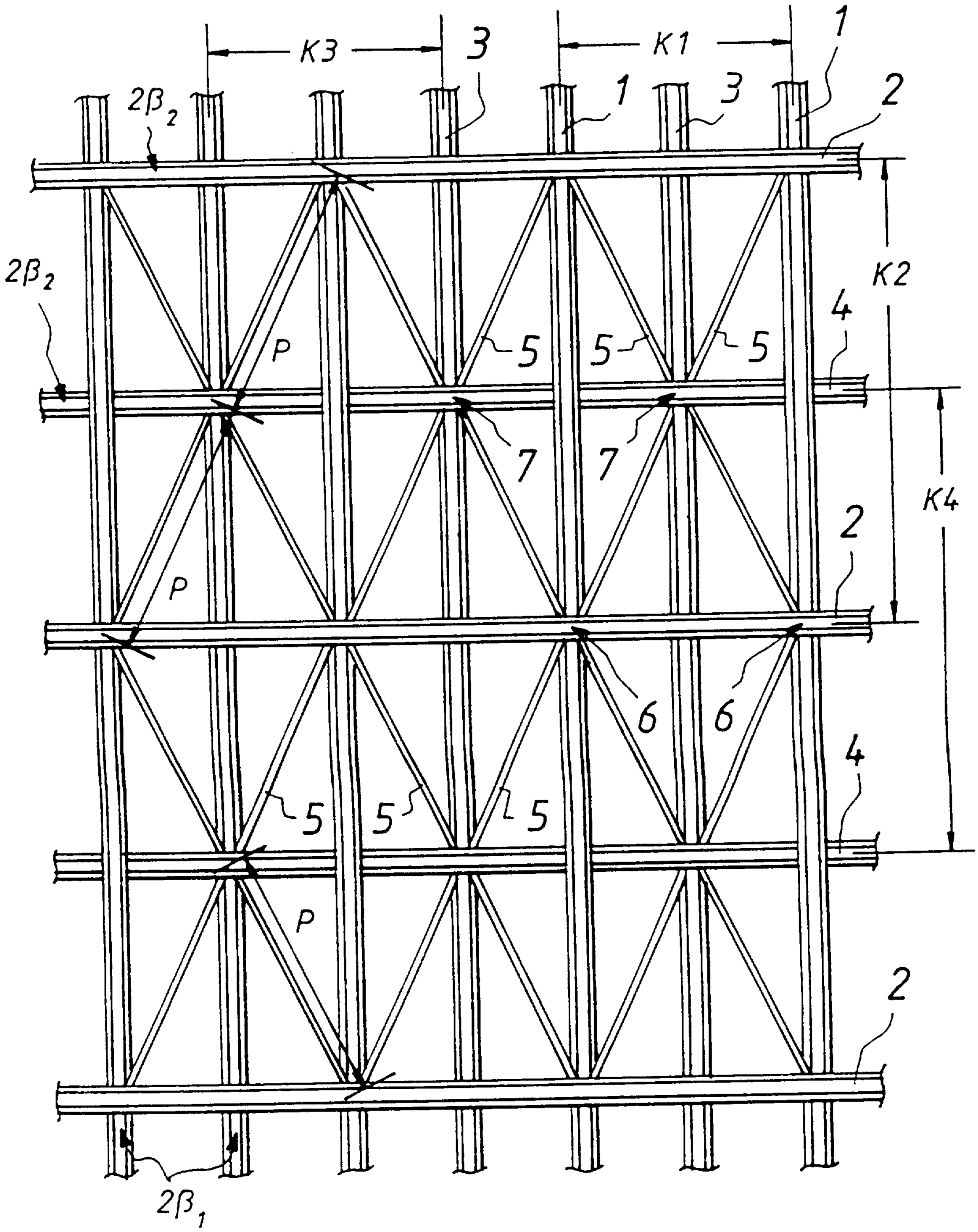
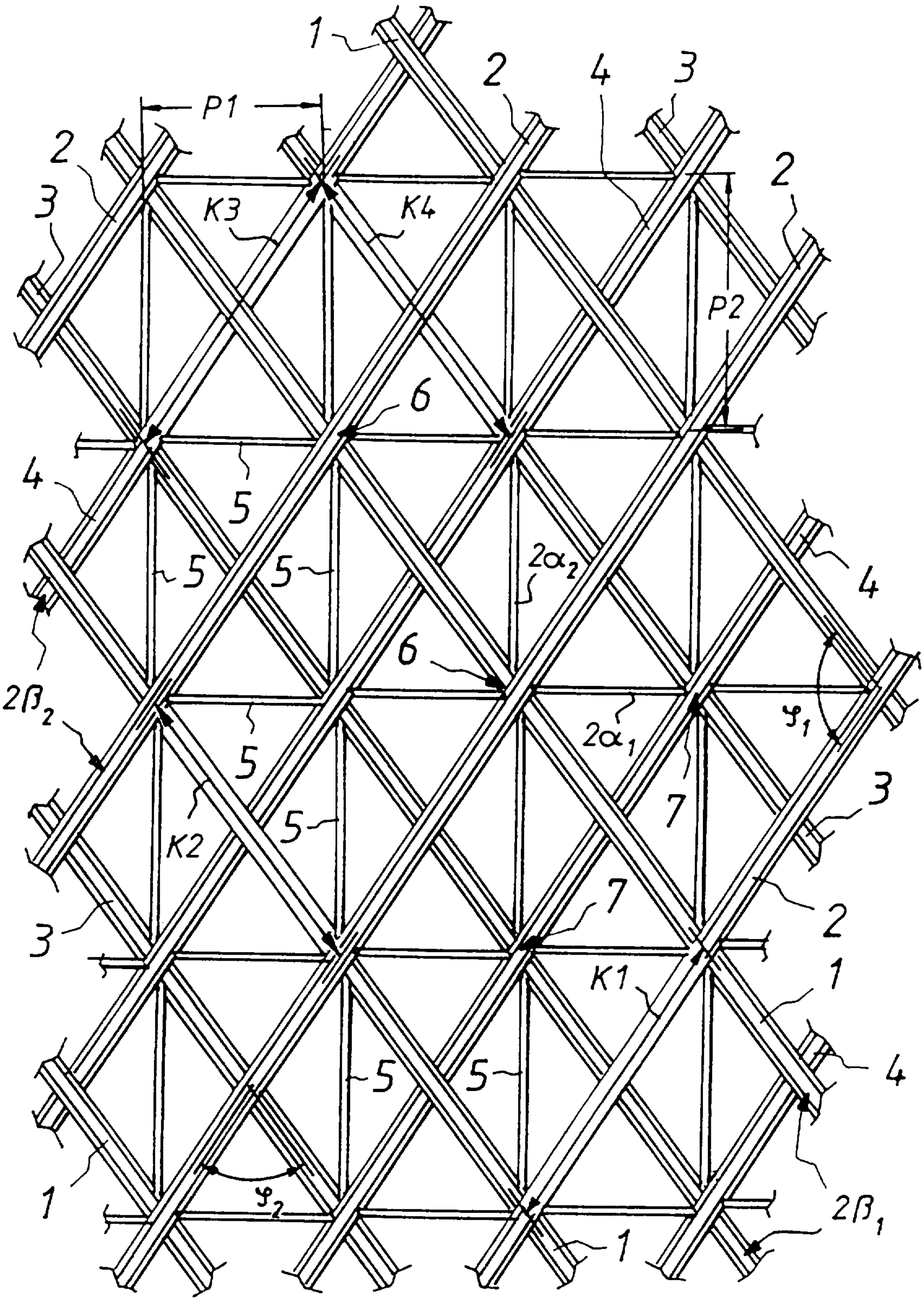


Fig. 7


1
P1
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2
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K3
K4
P2
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5
5
5
2α2
4
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2β2
5
2α1
φ1
7
5
K2
5
3
3
7
2
K1
1
5
5
4
1
φ2
1
2β1

Fig.8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 96/00079

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: E04B 1/19
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: E04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 8203236 A1 (WALLEN, L.R. ET AL), 30 Sept 1982 (30.09.82), page 3, line 2 - page 6, line 8, figures 1-7 --	1,3,4,8,15, 16
A	EP 0225299 A2 (BURATTI, M.M. ET AL), 10 June 1987 (10.06.87), figures 1,4,14, abstract --	1-17
A	DE 2445515 B2 (FA. ERWIN MEHNE), 7 June 1979 (07.06.79), column 3, line 64 - column 4, line 36, figures 1-4 --	1-17

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 May 1996	09 -05- 1996

Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Ingemar Hedlund Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 96/00079

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9322515 A1 (ASW-CUBIC STRUCTURES LIMITED), 11 November 1993 (11.11.93), figure 5, abstract -- --------	1-17

INTERNATIONAL SEARCH REPORT
Information on patent family members

01/04/96

International application No.
PCT/FI 96/00079

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A1- 8203236	30/09/82	EP-A,A- 0085679	17/08/83
EP-A2- 0225299	10/06/87	NONE	
DE-B2- 2445515	07/06/79	FR-A,B- 2286249	23/04/76
WO-A1- 9322515	11/11/93	NONE	