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(54) **METHOD FOR THE CONSTRUCTION OF A PRESTRESSED STRUCTURE AND PRESTRESSED STRUCTURE THUS OBTAINED**

VERFAHREN ZUR KONSTRUKTION EINER VORGESPANNTEN STRUKTUR UND EINE SO
HERGESTELLTE STRUKTUR

PROCEDE DE FABRICATION DE STRUCTURES PRECONTRAINTES ET STRUCTURES
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Description

TECHNICAL FIELD AND BACKGROUND ART.

[0001] The present invention relates to a method for the construction of a prestressed structure and to the prestressed structure thus obtained. In the art various types of prestressed structures are known.

[0002] It is known the Patent GB 1543069 A in which prestressed wooden construction elements are described having a set of prestressing strands, some of them fastened to the edges of the wooden support beam and the others having at least one end attached to an intermediate point of the support beam; a drawback concerning mainly one of the shown embodiments of the construction elements is that it is necessary to make ducts inside the support beam in order to position the strands; a drawback concerning another embodiment is that the tensioning operations of the strand are not easy, the strands being positioned on the two sides of the wooden support beam.

[0003] It is also known the Patent CH 284016 A in which a prestressed wooden beam is described comprising two wooden elements between which strands are positioned; a drawback concerning this embodiment is that the prestressed beam has a low lateral stability.

[0004] In a prestressed beam, as it is known, steel reinforcements are used, said reinforcements, suitably tensioned, inducing in the said beam a compressive normal force, bending moments and, in some cases, shear forces. Beams made of prestressed concrete are very widespread.

DISCLOSURE OF INVENTION.

[0005] The object of the present invention is that of providing prestressed structures which comprise glued laminated timber beams and tendons of the "external" type and which have considerable transverse stability. These and other objects are achieved by the method for the construction of a prestressed structure according to the present invention and by the prestressed structure thus obtained, also according to the present invention.

[0006] The abovementioned method for the construction of a prestressed structure is characterized by the fact that it comprises the following steps:

- first step: two or more glued laminated timber beams, two terminal elements, one or more deviating elements and one or more tendons are made; each of said terminal elements consists of a set of metal elements which comprises two or more end-pieces and one or more cross-pieces which are joined to said two or more end-pieces; each of said end-pieces is to be in contact with one end of one of said two or more glued laminated timber beams; each of said one or more deviating elements consists of a set of metal elements which comprises elements

to be placed in contact with said glued laminated timber beams and suitably shaped elements which are to be placed in contact with said tendons; said glued laminated timber

beams, said terminal elements, said one or more deviating elements and said one or more tendons, from the start, are designed and made so as to produce the prestressed structure;

- second step: a primary structure is assembled, applying said terminal elements and said one or more deviating elements to said glued laminated timber beams; said terminal elements are applied to the ends of said glued laminated timber beams; at the end of said second step of the method, said glued laminated timber beams are spaced from one another and are connected together by means of said terminal elements and of said one or more deviating elements;

- third step: said one or more tendons are arranged in position, in contact with said one or more deviating elements and with said terminal elements; at the location of said one or more deviating elements, the path followed by said one or more tendons changes direction; each of said one or more tendons is located outside the cross-section of said glued laminated timber beams and is positioned, at least partly, between said glued laminated timber beams;

- fourth step: tensioning of said one or more tendons is performed, said tendons being then anchored, at their ends, to said terminal elements; said tensioning is performed using means which act against said glued laminated timber beams through the terminal element with which said means are in contact; each of said one or more tendons, during said tensioning, being subject to a tensile normal force, lengthens, sliding longitudinally with respect to said primary structure; following said tensioning, said one or more tendons, at the location of said terminal elements and of said one or more deviating elements, apply to said primary structure a system of forces which produces bending in said primary structure, inducing in said primary structure a compressive normal force; said fourth step of the method is completed before the prestressed structure is put into service.

[0007] The prestressed structure obtained in accordance with the method described above (prestressed structure which also forms the subject of the present invention) is characterized by the fact that it comprises in combination:

- a primary structure comprising two or more glued laminated timber beams, two terminal elements applied to the ends of said glued laminated timber beams and one or more deviating elements applied to said glued laminated timber beams; said glued laminated timber beams are spaced from one another and are connected together by means of said ter-

terminal elements and of said one or more deviating elements;

- one or more tendons, each of which has its ends anchored to said terminal elements and is in contact with said one or more deviating elements; each of said terminal elements consists of a set of metal elements which comprises two or more end-pieces and one or more cross-pieces which are joined to said two or more end-pieces; each of said end-pieces is in contact with one end of one of said two or more glued laminated timber beams; each of said one or more deviating elements consists of a set of metal elements which comprises elements placed in contact with said glued laminated timber beams and suitably shaped elements which are placed in contact with said tendons; at the location of said one or more deviating elements the path followed by said one or more tendons changes direction; each of said one or more tendons is located outside the cross-section of said glued laminated timber beams and is positioned, at least partly, between said glued laminated timber beams; said one or more tendons, at the location of said terminal elements and of said one or more deviating elements, apply to said primary structure forces which produce bending in said primary structure, inducing in said primary structure a compressive normal force; said forces are due to the tensioning of said one or more tendons, performed during the construction of the prestressed structure, and to the loads applied to said prestressed structure; in particular, as a result of said tensioning, said one or more tendons, at the location of said terminal elements and of said one or more deviating elements, apply to said primary structure a system of forces which produces bending in said primary structure, inducing in said primary structure a compressive normal force.

BRIEF DESCRIPTION OF DRAWINGS.

[0008] The characteristic features and advantages of the present invention will emerge more clearly from the following description of two embodiments illustrated purely by way of a non-limiting example in the accompanying plates of drawings, in which:

- Figure 1 shows a partly longitudinal view and partly longitudinally sectioned view of a prestressed structure obtained according to the present invention;
- Figure 2 shows, on a scale larger than that of Figure 1, the cross-section along the line I-I of Figure 1;
- Figure 3 shows, on the same scale as figure 2, a detail of Figure 1;
- Figure 4 shows, on the same scale as Figure 2, the view, from one of the two ends, of the prestressed structure according to Figure 1;
- Figure 5 shows a partly longitudinal view and partly

longitudinally sectioned view of a prestressed structure obtained in accordance with the present invention, according to a further embodiment;

- Figure 6 shows, on a larger scale than that of Figure 5, the cross-section along the line II-II of Figure 5.

[0009] For the sake of simplicity of the illustration, welding, bolting, nailing or other joining systems have not been shown in the abovementioned figures.

BEST MODE FOR CARRYING OUT THE INVENTION.

[0010] Below, in order to facilitate the understanding of the steps of the method according to the present invention, first of all, with reference to Figures 1, 2, 3 and 4, a prestressed structure 1 obtained according to the present invention is described. The prestressed structure 1, which below is described when in use, is supported at its ends; more precisely, it is constrained with two external constraints 2, each of which is schematically represented as a hinge, and with two external constraints 3, each of which is schematically represented as a horizontally rolling support. The prestressed structure 1, which (during use) is subject to vertical concentrated loads 4, comprises in combination:

- a primary structure 5 comprising two glued laminated timber beams (glulam beams) 5a, two terminal elements 5b applied to the ends of the two glued laminated timber beams 5a and five deviating elements 5c, 5d, 5e applied to the two glued laminated timber beams 5a; the glued laminated timber beams 5a are spaced from each other and are connected together by means of the terminal elements 5b and of the deviating elements 5c, 5d, 5e; the glued laminated timber beams 5a, which have a straight and horizontal axis, have a rectangular cross-section; the glued laminated timber beams 5a are identical and parallel to each other; each of the two glued laminated timber beams 5a consists of the set of two glued laminated timber beams 6 which are identical to each other and have a rectangular cross-section and which are placed in contact with each other and joined together;
- eight tendons 7, each of which has its ends anchored to the two terminal elements 5b and is in contact with the five deviating elements 5c, 5d, 5e; at the location of the deviating elements 5c, 5d, 5e, the path followed by the tendons 7 changes direction; each tendon 7 is located outside the cross-section of the two glued laminated timber beams 5a and is positioned, partly (i.e. along the portions close to its ends), between the said two glued laminated timber beams 5a; it is pointed out that the expression "positioned partly between the two glued laminated timber beams 5a" is understood as meaning "positioned partly in the space between the two glued laminated timber beams 5a"; the tendons 7, at the location of

the terminal elements 5b and of the deviating elements 5c, 5d, 5e, apply to the primary structure 5 forces which produce bending in the primary structure 5, inducing in the said primary structure 5 a compressive normal force; the abovementioned forces are due to the tensioning of the tendons 7, performed during the construction of the prestressed structure 1, and to the loads 4 which are applied, during use, to the prestressed structure 1 itself; in particular, as a result of the abovementioned tensioning, the tendons 7, at the location of the terminal elements 5b and of the deviating elements 5c, 5d, 5e, apply to the primary structure 5 a system of forces which produces (upwards) bending in the primary structure 5, inducing in the said primary structure 5 a compressive normal force. It is pointed out that the intensity of the forces applied by the tendons 7 to the primary structure 5 is influenced by the decrease in tension due (among other things) to the relaxation of the steel and to the long-term deformations (creep) of the glued laminated timber. Each tendon 7 consists of a high-strength steel strand (steel, that is, having for example a tensile strength greater than 1750 N/mm²) contained in its own sheath of synthetic material inside which the strand itself is able to slide. Each of the two terminal elements 5b consists of a set of metal elements which comprises two end-pieces 8, each of which is in contact with one of the two glued laminated timber beams 5a, two cross-pieces 9a, 9b which are joined to the two end-pieces 8 and an anchoring element 10 which is joined to the cross-piece 9a; the tendons 7 are anchored at the location of the anchoring elements 10 by means of wedges. It is pointed out that, according to a variation, not shown in the figures, with reference to each of the two terminal elements, the end-pieces, as well as the end cross-sections of the glued laminated timber beams, are substantially perpendicular not to the axes of the said glued laminated timber beams, but to the axes of the tendons which are anchored at the location of the terminal element itself. It is pointed out that, according to another embodiment, not shown in the figures, the end-pieces may have dimensions which are smaller than the height of the cross-section of the glued laminated timber beams. Each of the five deviating elements 5c, 5d, 5e consists of a set of metal elements which comprises elements placed in contact with the glued laminated timber beams 5a and suitably shaped elements which, placed in contact with the tendons 7, deviate the path of the said tendons 7. It is pointed out that, in the prestressed structure 1, the axes of the deviating elements 5c, 5d, 5e are vertical and are perpendicular to the axes of the two glued laminated timber beams 5a; according to a variation, not shown in the figures, the axis of each deviating element is directed along the bisector of the angle formed between the two sections of each tendon located re-

spectively on either side of the said deviating element.

[0011] The method, according to the present invention, for the construction of the prestressed structure 1 is described below, said method comprising the following steps:

- first step: the two glued laminated timber beams 5a, the two terminal elements 5b, the five deviating elements 5c, 5d, 5e and the eight tendons 7 are made; the two glued laminated timber beams 5a, the terminal elements 5b, the deviating elements 5c, 5d, 5e and the tendons 7, from the start, are designed and made so as to produce the prestressed structure 1;
- second step: the primary structure 5 is assembled on-site, applying the terminal elements 5b and the deviating elements 5c, 5d, 5e to the two glued laminated timber beams 5a; the terminal elements 5b are applied to the ends of the glued laminated timber beams 5a; at the end of the second step of the method, the two glued laminated timber beams 5a are spaced from each other and are connected together by means of the terminal elements 5b and of the deviating elements 5c, 5d, 5e;
- third step: the tendons 7 are arranged in position, in contact with the deviating elements 5c, 5d, 5e and with the terminal elements 5b; at the location of the deviating elements 5c, 5d, 5e the path followed by the tendons 7 changes direction; each tendon 7 is located outside the cross-section of the two glued laminated timber beams 5a and is positioned, partly, between the said two glued laminated timber beams 5a; it is pointed out that the tendons 7 are inserted inside the deviating elements 5c, 5d, 5e so as to be in contact with the suitably formed metal elements referred to above; then the primary structure 5, with the tendons 7 already arranged in position (as described above), is installed, positioning it on the external constraints 2 and the external constraints 3;
- fourth step: tensioning of the tendons 7 is performed, said tendons being then anchored, at their ends, to the terminal elements 5b; the abovementioned tensioning is performed using a hydraulic jack (not shown in the figures) which acts against the two glued laminated timber beams 5a through the terminal element 5b with which said hydraulic jack is in contact; each tendon 7, during the abovementioned tensioning operation, being subject to a tensile normal force, lengthens, sliding longitudinally with respect to the primary structure 5; following the abovementioned tensioning, the tendons 7, at the location of the terminal elements 5b and of the deviating elements 5c, 5d, 5e, apply to the primary structure 5 a system of forces which produces bending in the primary structure 5, inducing in the said primary structure 5 a compressive normal force; the fourth step of the method is completed before the pre-

stressed structure 1 is put into service.

[0012] With respect to the fourth step of the method the following is pointed out: the hydraulic jack, mentioned above, which is positioned at the location of the terminal element 5b close to the external constraints 3, tensions, in accordance with a suitable tensioning sequence, the tendons 7, acting, by means of the said terminal element 5b (close to the external constraints 3), against the two glued laminated timber beams 5a; the ends of the tendons 7 close to the external constraints 2 have been previously anchored, by means of the associated wedges, to the terminal element 5b close to the said external constraints 2; during the tensioning operations each tendon 7 slides, except for its end close to the external constraints 2, with respect to the primary structure 5, substantially (the term "substantially" is used since frictional forces are present) free to slide along its whole length inside its sheath. Then, after the tendons 7 have been anchored by means of the associated wedges to the terminal element 5b close to the external constraints 3, in order to obtain (as far as possible) a symmetrical distribution of the stresses, by means of the abovementioned jack, which is now positioned at the location of the terminal element 5b close to the external constraints 2, the operations of tensioning of the said tendons 7 are completed. The hydraulic jack is then deactivated and definitively removed. The result is that, at the end of the fourth step of the method, the ends of the tendons 7 are definitively anchored to the terminal elements 5b. The fourth step of the method terminates with the completion of the operations described above. The method for the construction of the prestressed structure 1 is concluded with termination of the fourth step. Then, once the method has been terminated, the prestressed structure 1 is put into service and the loads 4 are applied to it.

[0013] Figures 5 and 6 illustrate a prestressed structure 20 obtained according to the present invention, which is supported at its ends on two external constraints 21, each of which is schematically represented by a hinge, and on two external constraints 22, each of which is schematically represented by a horizontally rolling support. The prestressed structure 20, which is described below during use, is subject to vertical concentrated loads 23 and comprises in combination:

- a primary structure 24 comprising two glued laminated timber beams 24a with a rectangular cross-section, two metal terminal elements 24b which are applied to the ends of the two glued laminated timber beams 24a, two metal deviating elements 24c applied to the two glued laminated timber beams 24a, and metal connection elements 24d applied to the two glued laminated timber beams 24a; the two glued laminated timber beams 24a are spaced from each other and are connected together by means of the terminal elements 24b, of the deviating elements 24c and of the connection elements 24d; the two

glued laminated timber beams 24a have a straight and horizontal axis;

- six tendons 25, each of which has its ends anchored to the terminal elements 24b and is in contact with the deviating elements 24c; each tendon 25 consists of a high-strength steel strand contained inside a sheath of synthetic material inside which the strand itself is able to slide.

[0014] It is pointed out that, for the sake of simplicity of the illustration, structural steel elements, which are arranged in an X shape and located in the horizontal plane which contains the axes of the connection elements 24d, have not been shown in Figures 5 and 6: the abovementioned structural elements arranged in an X shape complete the formation of a bracing structural system situated in the plane in which said elements lie. According to another embodiment, not shown in the figures, the connection elements (mentioned above) may be made of glued laminated timber. The behaviour of the prestressed structure 20 and the method for the construction thereof are technically equivalent to those already described for the prestressed structure 1. It is pointed out that, during the first step of the method, the connection elements 24d are also made, which elements, during the second step of the method, are applied to the two glued laminated timber beams 24a.

[0015] In general, the method according to the present invention may sometimes comprise a fifth step, following the first four steps, during which relative displacements, permitted during the fourth step of the method, between the one or more tendons and the primary structure are permanently prevented; the abovementioned possible fifth step of the method is completed before the prestressed structure is put into service. In general the possible fifth step of the method may be useful for optimizing the behaviour in the "ultimate state" of the prestressed structure. With reference to the method according to the present invention for the construction of a prestressed structure, generally, some of the permanent loads or all the permanent loads may be applied to the said structure before the start of the fourth step of the method.

[0016] In a prestressed structure obtained according to the present invention each of the two or more glued laminated timber beams comprised in the primary structure may consist of the set of two (as in the case of each of the glued laminated timber beams 5a) or more glued laminated timber beams, with a rectangular cross-section, which are arranged in contact with one another and joined together so as to form a single beam. In a prestressed structure obtained according to the present invention each of the two or more glued laminated timber beams included in the primary structure may have a straight axis or curved axis or axis formed as a broken line (with possible connecting radii). In a prestressed structure obtained according to the present invention the two or more glued laminated timber beams (included in the primary structure) may be of the solid-wall type or

truss type or Vierendeel type or other types; in the case where the glued laminated timber beams are of the solid-wall type, each of them may have (for example) a rectangular cross-section or T-shaped cross-section or I-shaped cross-section with the upper flange the same as the lower flange or different from the lower flange. In a prestressed structure obtained according to the present invention each of the two or more glued laminated timber beams (included in the primary structure) may have a constant cross-section or a variable cross-section. In a prestressed structure obtained according to the present invention each of the two or more glued laminated timber beams (included in the primary structure) may comprise two or more segments joined together and located, in the longitudinal direction, one after another; these segments are assembled on-site before implementing the third step of the method; it is pointed out that, generally, the stress states at the location of the joints between the above-mentioned segments may be improved as a result of the prestressing. It is possible to have a prestressed structure obtained according to the present invention (this embodiment is not illustrated in the figures) in which each tendon is entirely positioned between the glued laminated timber beams (i.e. is entirely positioned in the space between the glued laminated timber beams). It is therefore possible to have a prestressed structure obtained according to the present invention in which only one tendon is present. It is possible to have a prestressed structure obtained according to the present invention in which the tendons consist of high-strength steel strands grouped together in one or more groups of strands; each of the abovementioned groups of strands is contained in a tubular housing element which is made of synthetic material and inside which a filling material has also been introduced; it is pointed out that each strand may be greased and contained inside its own sheath made of synthetic material such that sliding of each strand inside its sheath is permitted. It is possible to have a prestressed structure obtained according to the present invention in which a single deviating element is present. It is possible to have a prestressed structure obtained according to the present invention in which more than two glued laminated timber beams are present; these glued laminated timber beams are spaced from one another and are connected together by means of the terminal elements and of the one or more deviating elements; it is pointed out that connection elements applied to the abovementioned glued laminated timber beams may also be present. In a prestressed structure obtained according to the present invention the tendons consist, for example, of strands or bars or wires; it is pointed out that the tendons may be made of steel or may be made using synthetic materials or composite materials or also other suitable materials.

[0017] It is possible to have a prestressed structure obtained according to the present invention (not shown in the figures) in which the primary structure also comprises retaining elements which connect the primary structure and the tendons at points where the path fol-

lowed by the tendons does not change direction. According to the present invention it is possible to produce, in addition to prestressed structures externally constrained in an isostatic manner, also prestressed structure externally constrained in a hyperstatic manner. An advantage of the present invention consists in the fact that, using a prestressed structure obtained according to the present invention instead of an "equivalent" traditional glued laminated timber beam, it is possible to reduce the quantity of glued laminated timber to be used.

Claims

1. Method for the construction of a prestressed structure, **characterized in that** it comprises the following steps:

- first step: two or more glued laminated timber beams (5a, 24a), two terminal elements (5b, 24b), one or more deviating elements (5c, 5d, 5e, 24c) and one or more tendons (7, 25) are made;

- each of said terminal elements consists of a set of metal elements which comprises two or more end-pieces (8) and one or more cross-pieces (9a, 9b) which are joined to said two or more end-pieces; each of said end-pieces is to be in contact with one end of one of the two or more glued laminated timber beams (5a, 24a); each of said one or more deviating elements consists of a set of metal elements which comprises elements to be placed in contact with the glued laminated timber beams (5a, 24a) and suitably shaped elements which are to be placed in contact with the tendons (7, 25);

- the glued laminated timber beams (5a, 24a), the terminal elements (5b, 24b), the one or more deviating elements (5c, 5d, 5e, 24c) and the one or more tendons (7, 25), from the start, are designed and made so as to produce the prestressed structure (1, 20);

- second step: a primary structure (5, 24) is assembled, applying the terminal elements (5b, 24b) and the one or more deviating elements (5c, 5d, 5e, 24c) to the glued laminated timber beams (5a, 24a); the terminal elements (5b, 24b) are applied to the ends of the glued laminated timber beams (5a, 24a); at the end of said second step of the method, the glued laminated timber beams (5a, 24a) are spaced from one another and are connected together by means of the terminal elements (5b, 24b) and of the one or more deviating elements (5c, 5d, 5e, 24c);

- third step: the one or more tendons (7, 25) are arranged in position, in contact with the one or more deviating elements (5c, 5d, 5e, 24c) and with the terminal elements (5b, 24b); at the lo-

- cation of the one or more deviating elements (5c, 5d, 5e, 24c) the path followed by the one or more tendons (7, 25) changes direction; each of the one or more tendons (7, 25) is located outside the cross-section of the glued laminated timber beams (5a, 24a) and is positioned, at least partly, between said glued laminated timber beams;
- fourth step: tensioning of the one or more tendons (7, 25) is performed, said tendons being then anchored, at their ends, to the terminal elements (5b, 24b); said tensioning is performed using means which act against the glued laminated timber beams (5a, 24a) through the terminal element (5b, 24b) with which said means are in contact; each of the one or more tendons (7, 25), during said tensioning, being subject to a tensile normal force, lengthens, sliding longitudinally with respect to the primary structure (5, 24); following said tensioning, the one or more tendons (7, 25), at the location of the terminal elements (5b, 24b) and of the one or more deviating elements (5c, 5d, 5e, 24c), apply to the primary structure (5, 24) a system of forces which produces bending in said primary structure, inducing in said primary structure a compressive normal force; said fourth step of the method is completed before the prestressed structure (1, 20) is put into service.
2. Method according to Claim 1, **characterized in that** it comprises a fifth step, following the first four steps, during which relative displacements, permitted during the fourth step of the method, between one or more tendons and the primary structure are permanently prevented; said fifth step of the method is completed before the prestressed structure is put into service.
3. Method according to Claim 1, **characterized in that**, during the first step of said method, connection elements (24d) are made, which elements, during the second step of said method, are applied to the two or more glued laminated timber beams (24a).
4. Prestressed structure obtained according to the method according to Claim 1, **characterized in that** it comprises in combination:
- a primary structure (5, 24) comprising two or more glued laminated timber beams (5a, 24a), two terminal elements (5b, 24b) applied to the ends of said glued laminated timber beams and one or more deviating elements (5c, 5d, 5e, 24c) applied to said glued laminated timber beams; the glued laminated timber beams (5a, 24a) are spaced from one another and are connected together by means of the terminal elements (5b,
- 24b) and of the one or more deviating elements (5c, 5d, 5e, 24c);
- one or more tendons (7, 25), each of which has its ends anchored to the terminal elements (5b, 24b) and is in contact with the one or more deviating elements (5c, 5d, 5e, 24c); each of said terminal elements consists of a set of metal elements which comprises two or more end-pieces (8) and one or more cross-pieces (9a, 9b) which are joined to said two or more end-pieces; each of said end-pieces is in contact with one end of one of the two or more glued laminated timber beams (5a, 24a); each of said one or more deviating elements consists of a set of metal elements which comprises elements placed in contact with the glued laminated timber beams (5a, 24a) and suitably shaped elements which are placed in contact with the tendons (7, 25);
- at the location of the one or more deviating elements (5c, 5d, 5e, 24c) the path followed by the one or more tendons (7, 25) changes direction; each of the one or more tendons (7, 25) is located outside the cross-section of the glued laminated timber beams (5a, 24a) and is positioned, at least partly, between said glued laminated timber beams; the one or more tendons (7, 25), at the location of the terminal elements (5b, 24b) and of the one or more deviating elements (5c, 5d, 5e, 24c), apply to the primary structure (5, 24) forces which produce bending in said primary structure, inducing in said primary structure a compressive normal force; said forces are due to the tensioning of the one or more tendons (7, 25), performed during the construction of the prestressed structure (1, 20), and to the loads (4, 23) applied to said prestressed structure; in particular, as a result of said tensioning, the one or more tendons (7, 25), at the location of the terminal elements (5b, 24b) and of the one or more deviating elements (5c, 5d, 5e, 24c), apply to the primary structure (5, 24) a system of forces which produces bending in said primary structure, inducing in said primary structure a compressive normal force.
5. Prestressed structure according to Claim 4, **characterized in that** the primary structure (24) comprises connection elements (24d) applied to the two or more glued laminated timber beams (24a); the glued laminated timber beams (24a) are spaced from one another and are connected together also by means of the connection elements (24d).
6. Prestressed structure according to Claim 4, **characterized in that** each of the two or more glued laminated timber beams (5a) consists of the set of two or more glued laminated timber beams (6), with a

rectangular cross-section, which are arranged in contact with one another and joined together so as to form a single beam.

7. Prestressed structure according to Claim 4, **characterized in that** the two or more glued laminated timber beams (5a, 24a) have a straight axis and have a rectangular cross-section. 5
8. Prestressed structure according to Claim 4, **characterized in that** each of the two or more glued laminated timber beams has a curved axis or axis formed as a broken line. 10
9. Prestressed structure according to Claim 4, **characterized in that** each of the two or more glued laminated timber beams has a T-shaped cross-section or I-shaped cross-section with the upper flange the same as the lower flange or different from the lower flange. 15
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10. Prestressed structure according to Claim 4, **characterized in that** each of the two or more glued laminated timber beams comprises two or more segments joined together and located, in the longitudinal direction, one after another. 25

Patentansprüche

1. Verfahren zur Konstruktion einer vorgespannten Struktur, **dadurch gekennzeichnet, dass** es die folgenden Schritte aufweist: 30
 - erster Schritt: zwei oder mehr geklebte laminierte Holzträger (5a, 24a), zwei Endelemente (5b, 24b), ein oder mehrere Deviationselemente (5c, 5d, 5e, 24c) und ein oder mehrere Vorspannglieder (7, 25) werden hergestellt; 35
 - jedes Endelement besteht aus einem Satz aus Metallelementen, welcher zwei oder mehr Endstücke (8) und eines oder mehrere Kreuzstücke (9a, 9b), die an den zwei oder mehr Endstücken befestigt sind, aufweist; jedes der Endstücke muss in Kontakt mit einem Ende von einem der zwei oder mehr geklebten laminierten Holzträger (5a, 24a) sein; jedes von dem einen oder den mehreren Deviationselementen besteht aus einem Satz aus Metallelementen, welcher Elemente, die in Kontakt mit den geklebten laminierten Holzträgern (5a, 24a) zu platzieren sind, und geeignet geformte Elemente, die in Kontakt mit den Vorspanngliedern (7, 25) zu platzieren sind, aufweist; 40
 - die geklebten laminierten Holzträger (5a, 24a), die Endelemente (5b, 24b), das eine oder die mehreren Deviationselemente (5c, 5d, 5e, 24c) und das eine oder die mehreren Vorspannglieder 45

der (7, 25) sind vom Start an so ausgestaltet und gemacht, um die vorgespannte Struktur (1, 20) zu produzieren;

- zweiter Schritt: eine Primärstruktur (5, 24) wird zusammengebaut, wobei die Endelemente (5b, 24b) und das eine oder die mehreren Deviationselemente (5c, 5d, 5e, 24c) an den geklebten laminierten Holzträgern (5a, 24a) angebracht werden; die Endelemente (5b, 24b) werden an den Enden der geklebten laminierten Holzträger (5a, 24a) angebracht; am Ende des zweiten Schritts des Verfahrens sind die geklebten laminierten Holzträger (5a, 24a) beabstandet voneinander und mittels der Endelemente (5b, 24b) und des einen oder der mehreren Deviationselemente (5c, 5d, 5e, 24c) miteinander verbunden;

- dritter Schritt: das eine oder die mehreren Vorspannglieder (7, 25) werden in Position angeordnet, in Kontakt mit dem einen oder den mehreren Deviationselementen (5c, 5d, 5e, 24c) und mit den Endelementen (5b, 24b); am Ort des einen oder der mehreren Deviationselemente (5c, 5d, 5e, 24c) ändert der Pfad, dem das eine oder die mehreren Vorspannglieder (7, 25) folgen, die Richtung; jedes von dem einen oder den mehreren Vorspanngliedern (7, 25) ist außerhalb des Querschnitts der geklebten laminierten Holzträger (5a, 24a) gelegen und, zumindest teilweise, zwischen den geklebten laminierten Holzträgern positioniert;

- vierter Schritt: das Spannen von dem einen oder den mehreren Vorspanngliedern (7, 25) wird durchgeführt, wobei die Vorspannglieder dann an ihren Enden an den Endelementen (5b, 24b) verankert werden; das Spannen wird durch Verwendung von Mitteln durchgeführt, welche durch die Endelemente (5b, 24b), mit denen die Mittel in Kontakt sind, gegen die geklebten laminierten Holzträger (5a, 24a) wirken; wobei sich jedes von dem einen oder den mehreren Vorspanngliedern (7, 25) während des Spannens, während dessen es einer Zugnormalkraft ausgesetzt wird, verlängert, wobei es in Bezug auf die Primärstruktur (5, 24) longitudinal gleitet; nachfolgend dem Spannen bringen das eine oder die mehreren Vorspannglieder (7, 25) am Ort der Endelemente (5b, 24b) und des einen oder der mehreren Deviationselemente (5c, 5d, 5e, 24c) auf die Primärstruktur (5, 24) ein System aus Kräften auf, welches ein Biegen in der Primärstruktur produziert, wobei in der Primärstruktur eine Drucknormalkraft induziert wird; der vierte Schritt des Verfahrens ist abgeschlossen, bevor die vorgespannte Struktur (1, 20) in Betrieb genommen wird.

2. Verfahren gemäß Anspruch 1, **dadurch gekennzeichnet**

zeichnet, dass es einen fünften Schritt aufweist, der den ersten vier Schritten folgt, während dem relative Verschiebungen zwischen dem einen oder den mehreren Vorspanngliedern und der Primärstruktur, die während des vierten Schritts des Verfahrens gestattet sind, permanent verhindert werden; der fünfte Schritt des Verfahrens ist abgeschlossen, bevor die vorgespannte Struktur in Betrieb genommen wird.

3. Verfahren gemäß Anspruch 1, **dadurch gekennzeichnet, dass** während des ersten Schritts des Verfahrens Verbindungselemente (24d) hergestellt werden, die während des zweiten Schritts des Verfahrens an den zwei oder mehr geklebten laminierten Holzträgern (24a) angebracht werden.

4. Vorgespannte Struktur, die gemäß dem Verfahren gemäß Anspruch 1 erhalten wird, **dadurch gekennzeichnet, dass** sie in Kombination aufweist:

- eine Primärstruktur (5, 24), aufweisend zwei oder mehr geklebte laminierte Holzträger (5a, 24a), zwei Endelemente (5b, 24b), die an den Enden der geklebten laminierten Holzträger angeordnet sind, und eines oder mehrere Deviationselemente (5c, 5d, 5e, 24c), die an den geklebten laminierten Holzträgern angeordnet sind; die geklebten laminierten Holzträger (5a, 24a) sind beabstandet voneinander und mittels der Endelemente (5b, 24b) und des einen oder der mehreren Deviationselemente (5c, 5d, 5e, 24c) miteinander verbunden; eines oder mehrere Vorspannglieder (7, 25), wobei jedes seine Enden an den Endelementen (5b, 24b) verankert hat und in Kontakt mit dem einen oder den mehreren Deviationselementen (5c, 5d, 5e, 24c) ist; jedes der Endelemente besteht aus einem Satz aus Metallelementen, welcher zwei oder mehr Endstücke (8) und eines oder mehrere Kreuzstücke (9a, 9b), die an den zwei oder mehr Endstücken befestigt sind, aufweist; jedes der Endstücke ist in Kontakt mit einem Ende von einem der zwei oder mehr geklebten laminierten Holzträger (5a, 24a); jedes von dem einen oder den mehreren Deviationselementen besteht aus einem Satz aus Metallelementen, welcher Elemente, die in Kontakt mit den geklebten laminierten Holzträgern (5a, 24a) platziert sind, und geeignet geformte Elemente, die in Kontakt mit den Vorspanngliedern (7, 25) platziert sind, aufweist; am Ort des einen oder der mehreren Deviationselemente (5c, 5d, 5e, 24c) ändert der Pfad, dem das eine oder die mehreren Vorspannglieder (7, 25) folgen, die Richtung; jedes von dem einen oder den mehreren Vorspanngliedern (7, 25) ist außerhalb des Querschnitts der gekleb-

ten laminierten Holzträger (5a, 24a) gelegen und, zumindest teilweise, zwischen den geklebten laminierten Holzträgern positioniert; das eine oder die mehreren Vorspannglieder (7, 25) bringen am Ort der Endelemente (5b, 24b) und des einen oder der mehreren Deviationselemente (5c, 5d, 5e, 24c) Kräfte auf die Primärstruktur (5, 24) auf, die ein Biegen in der Primärstruktur produzieren, wobei in der Primärstruktur eine Drucknormalkraft induziert wird; diese Kräfte rühren her von dem Spannen des einen oder der mehreren Vorspannglieder (7, 25), das während der Konstruktion der vorgespannten Struktur (1, 20) ausgeführt wird, und von den Lasten (4,23), die der vorgespannten Struktur zugeführt werden; insbesondere bringen das eine oder die mehreren Vorspannglieder (7, 25) am Ort der Endelemente (5b, 24b) und des einen oder der mehreren Deviationselemente (5c, 5d, 5e, 24c) als ein Resultat des Spannens ein System von Kräften auf die Primärstruktur (5, 24) auf, welches ein Biegen in der Primärstruktur produziert, wobei in der Primärstruktur eine Drucknormalkraft induziert wird.

5. Vorgespannte Struktur gemäß Anspruch 4, **dadurch gekennzeichnet, dass** die Primärstruktur (24) Verbindungselemente (24d) aufweist, die an den zwei oder mehr geklebten laminierten Holzträgern (24a) angebracht sind; die geklebten laminierten Holzträger (24a) sind beabstandet voneinander und auch mittels der Verbindungselemente (24d) miteinander verbunden.

6. Vorgespannte Struktur gemäß Anspruch 4, **dadurch gekennzeichnet, dass** jeder der zwei oder mehr geklebten laminierten Holzträger (5a) aus dem Satz von zwei oder mehr geklebten laminierten Holzträgern (6) mit einem rechteckigen Querschnitt besteht, die in Kontakt miteinander angeordnet und miteinander verbunden sind, um einen einzigen Träger zu formen.

7. Vorgespannte Struktur gemäß Anspruch 4, **dadurch gekennzeichnet, dass** die zwei oder mehr geklebten laminierten Holzträger (5a, 24a) eine gerade Achse und einen rechteckigen Querschnitt aufweisen.

8. Vorgespannte Struktur gemäß Anspruch 4, **dadurch gekennzeichnet, dass** jeder der zwei oder mehr geklebten laminierten Holzträger eine kurvige Achse oder eine als gebrochene Linie geformte Achse aufweist.

9. Vorgespannte Struktur gemäß Anspruch 4, **dadurch gekennzeichnet, dass** jeder der zwei oder mehr geklebten laminierten Holzträger einen T-för-

migen Querschnitt oder einen I-förmigen Querschnitt aufweist, mit dem oberen Flansch gleich dem unteren Flansch oder verschieden vom unteren Flansch.

10. Vorgespannte Struktur gemäß Anspruch 4, **dadurch gekennzeichnet, dass** jeder der zwei oder mehr geklebten laminierten Holzträger zwei oder mehr Segmente aufweist, die miteinander verbunden sind und die, in longitudinaler Richtung, eines nach dem anderen gelegen sind.

Revendications

1. Méthode pour la construction d'une structure précontrainte, **caractérisée en ce qu'elle** comprend les phases suivantes:

- première phase: deux ou plusieurs poutres en bois laminé collé (5a, 24a), deux éléments terminaux (5b, 24b), un ou plusieurs éléments de déviation (5c, 5d, 5e, 24c) et un ou plusieurs câbles (7, 25) sont fabriqués; chacun desdits éléments terminaux consiste en un ensemble d'éléments métalliques comprenant deux ou plusieurs pièces d'extrémité (8) et une ou plusieurs pièces transversales (9a, 9b) jointes auxdites deux ou plusieurs pièces d'extrémité; chacune desdites pièces d'extrémité doit être en contact avec une extrémité de l'une des deux ou plusieurs poutres en bois laminé collé (5a, 24a); chacun desdits un ou plusieurs éléments de déviation consistant en un ensemble d'éléments métalliques comprenant des éléments à placer en contact avec les poutres en bois laminé collé (5a, 24a) et des éléments opportunément profilés devant être mis en contact avec les câbles (7, 25); les poutres en bois laminé collé (5a, 24a), les éléments terminaux (5b, 24b), le ou les éléments de déviation (5c, 5d, 5e, 24c) et le ou les câbles (7, 25), dès le début, sont conçus et fabriqués de manière à produire la structure précontrainte (1, 20);

- deuxième phase: une structure primaire (5, 24) est assemblée, en appliquant les éléments terminaux (5b, 24b) et le ou les éléments de déviation (5c, 5d, 5e, 24c) sur les poutres en bois laminé collé (5a, 24a); les éléments terminaux (5b, 24b) sont appliqués sur les extrémités des poutres en bois laminé collé (5a, 24a); au terme de ladite seconde phase de la méthode, les poutres en bois laminé collé (5a, 24a) sont espacées entre elles et sont reliées entre elles au moyen des éléments terminaux (5b, 24b) et du ou des éléments de déviation (5c, 5d, 5e, 24c);

- troisième phase: le ou les câbles (7, 25) sont mis en position, en contact avec le ou les élé-

ments de déviation (5c, 5d, 5e, 24c) et avec les éléments terminaux (5b, 24b); en correspondance du ou des éléments de déviation (5c, 5d, 5e, 24c), le parcours suivi par le ou les câbles (7, 25) change de direction; chacun du ou des câbles (7, 25) est situé à l'extérieur de la section transversale des poutres en bois laminé collé (5a, 24a) et est positionné, au moins partiellement, entre lesdites poutres en bois laminé collé;

- quatrième phase: la tension du ou des câbles (7, 25) est effectuée, lesdits câbles étant ancrés, en correspondance de leurs extrémités, sur les éléments terminaux (5b, 24b); ladite tension est effectuée en utilisant des moyens agissant contre les poutres en bois laminé collé (5a, 24a) par l'intermédiaire des éléments terminaux (5b, 24b) avec lesquels lesdits moyens sont en contact; chacun du ou des câbles (7, 25), pendant ladite mise en tension, étant soumis à une force de traction normale, s'allonge, en couissant longitudinalement par rapport à la structure primaire (5, 24); successivement à cette tension, le ou les câbles (7, 25), en correspondance des éléments terminaux (5b, 24b) et du ou des éléments de déviation (5c, 5d, 5e, 24c), imprime à la structure primaire (5, 24) un système de forces produisant une flexion dans ladite structure primaire, en induisant dans ladite structure primaire une force normale de compression; ladite quatrième phase de la méthode est réalisée avant que la structure précontrainte (1, 20) ne soit mise en service.

2. Méthode selon la revendication 1, **caractérisée en ce qu'elle** comprend une cinquième phase, suivant les premières quatre phases, pendant laquelle les déplacements relatifs, permis pendant la quatrième phase de la méthode, entre un ou plusieurs câbles et la structure primaire sont prévenus de manière permanente; ladite cinquième phase de la méthode est réalisée avant que la structure précontrainte ne soit mise en service.

3. Méthode selon la revendication 1, **caractérisée en ce que**, pendant la première phase de ladite méthode, des éléments de connexion (24d) sont réalisés, lesquels éléments, pendant la seconde phase de ladite méthode, sont appliqués sur les deux ou plusieurs poutres en bois laminé collé (24a).

4. Structure précontrainte obtenue selon la méthode selon la revendication 1, **caractérisée en ce qu'elle** comprend en combinaison:

- une structure primaire (5, 24) comprenant deux ou plus poutres en bois laminé collé (5a, 24a), deux éléments terminaux (5b, 24b) appliqués

sur les extrémités desdites poutres en bois laminé collé et un ou plusieurs éléments de déviation (5c, 5d, 5e, 24c) appliqués sur lesdites poutres en bois laminé collé; les poutres en bois laminé collé (5a, 24a) sont espacées entre elles et sont connectées entre elles au moyen des éléments terminaux (5b, 24b) et du ou des éléments de déviation (5c, 5d, 5e, 24c);

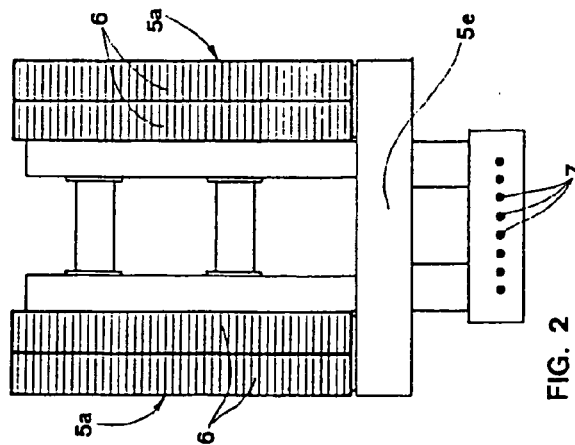
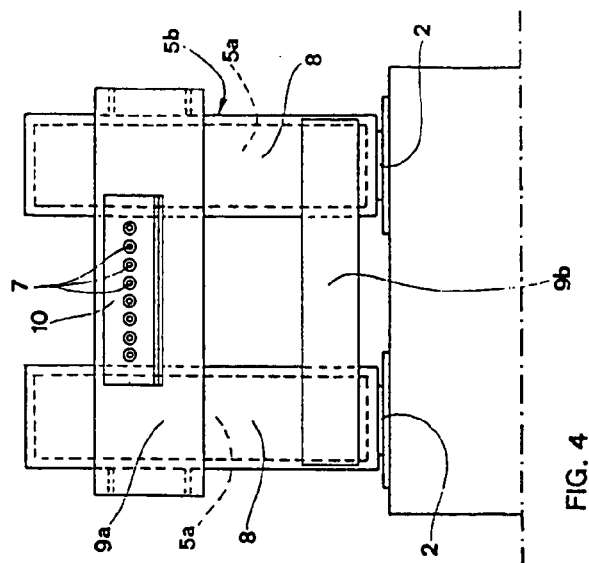
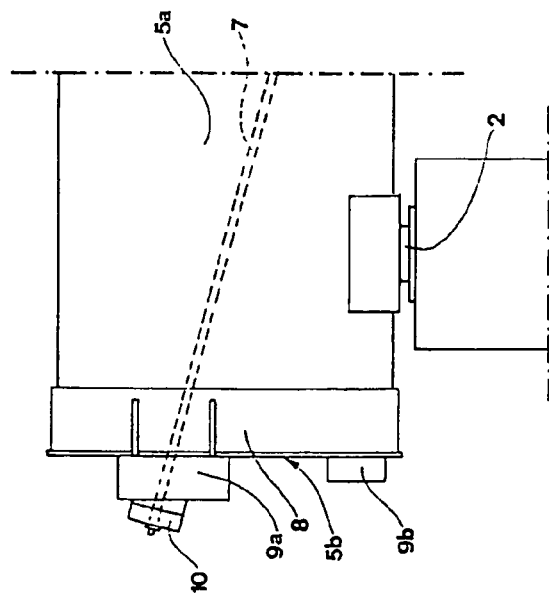
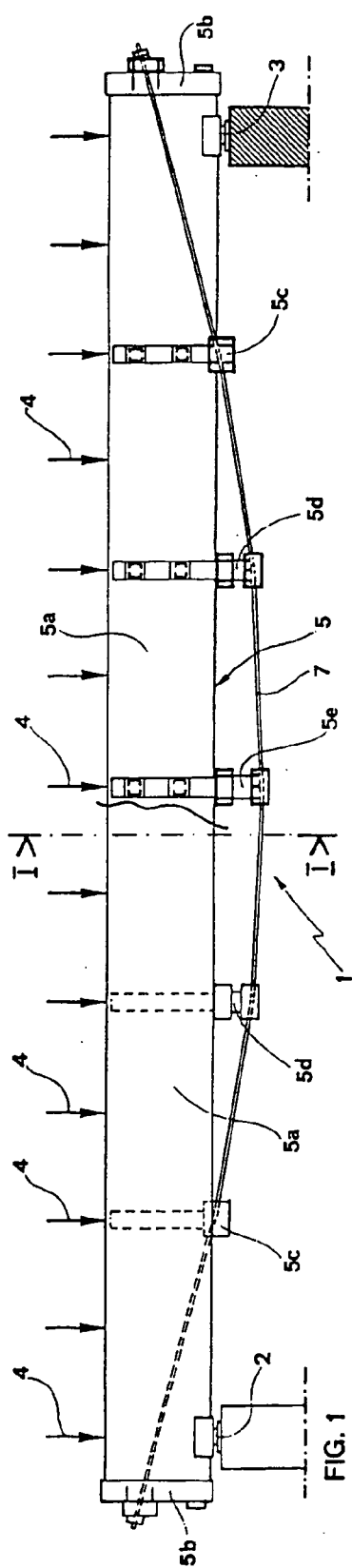
- un ou plusieurs câbles (7, 25), chacun desquels ayant ses extrémités ancrées sur les éléments terminaux (5b, 24b) et étant en contact avec le ou les éléments de déviation (5c, 5d, 5e, 24c); chacun des éléments terminaux consiste en un ensemble d'éléments métalliques comprenant une ou plusieurs pièces d'extrémité (8) et une ou plusieurs pièces transversales (9a, 9b) qui sont jointes auxdites deux ou plusieurs pièces d'extrémité; chacune desdites pièces d'extrémité est en contact avec une extrémité de l'une des deux ou plusieurs poutres en bois laminé collé (5a, 24a); chacun desdits un ou plusieurs éléments de déviation consistant en un ensemble d'éléments métalliques comprenant des éléments mis en contact avec les poutres en bois laminé collé (5a, 24a) et des éléments opportunément profilés mis en contact avec les câbles (7, 25);

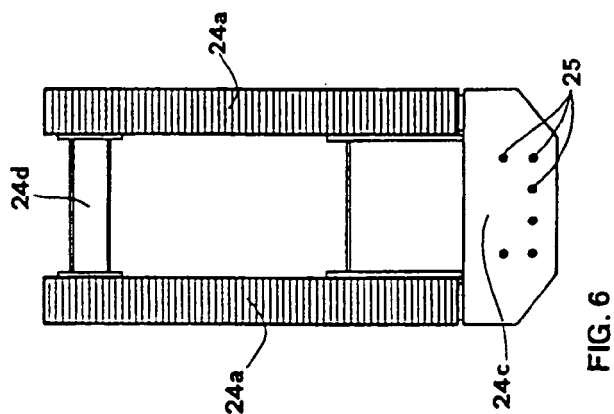
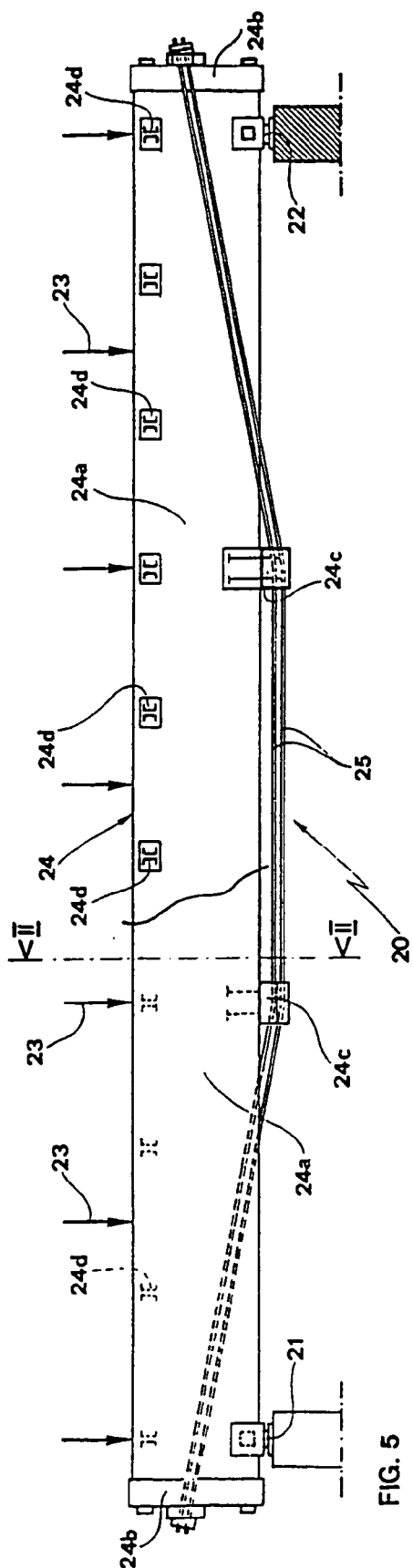
en correspondance du ou des éléments de déviation (5c, 5d, 5e, 24c), le parcours suivi par le ou les câbles (7, 25) change de direction; chacun du ou des câbles (7, 25) est situé à l'extérieur de la section transversale des poutres en bois laminé collé (5a, 24a) et est positionné, au moins partiellement, entre lesdites poutres en bois laminé collé; le ou les câbles (7, 25), en correspondance des éléments terminaux (5b, 24b) et du ou des éléments de déviation (5c, 5d, 5e, 24c), imprime sur la structure primaire (5, 24) des forces qui produisent une flexion dans ladite structure primaire, en induisant dans ladite structure primaire une force normale de compression; lesdites forces sont dues à la mise en tension du ou des câbles (7, 25), réalisée pendant la construction de la structure précontrainte (1, 20), et aux charges (4, 23) appliquées sur ladite structure précontrainte; en particulier, en conséquence de cette tension, le ou les câbles (7, 25), en correspondance des éléments terminaux (5b, 24b) et du ou des éléments de déviation (5c, 5d, 5e, 24c), appliquent sur la structure primaire (5, 24) un système de forces produisant une flexion dans ladite structure primaire, induisant dans ladite structure primaire une force normale de compression.

5. Structure précontrainte selon la revendication 4, **caractérisée en ce que** la structure primaire (24) comprend des éléments de connexion (24d) appliqués

sur les deux ou plusieurs poutres en bois laminé collé (24a); les poutres en bois laminé collé (24a) sont espacées entre elles et sont connectées entre elles également au moyen des éléments de connexion (24d).

6. Structure précontrainte selon la revendication 4, **caractérisée en ce que** chacune des deux ou plusieurs poutres en bois laminé collé (5a) consiste en l'ensemble de deux ou plusieurs poutres en bois laminé collé (6), avec une section transversale rectangulaire, qui sont disposées en contact entre elles et jointes entre elles de manière à former une seule poutre.
7. Structure précontrainte selon la revendication 4, **caractérisée en ce que** les deux ou plusieurs poutres en bois laminé collé (5a, 24a) présentent un axe rectiligne et une section transversale rectangulaire.
8. Structure précontrainte selon la revendication 4, **caractérisée en ce que** chacune des deux ou plusieurs poutres en bois laminé collé présente un axe courbé sous forme d'une ligne brisée.
9. Structure précontrainte selon la revendication 4, **caractérisée en ce que** chacune des deux ou plusieurs poutres en bois laminé collé présente une section en forme de T ou de I avec l'aile supérieure identique ou différente de l'aile inférieure.
10. Structure précontrainte selon la revendication 4, **caractérisée en ce que** chacune des deux ou plusieurs poutres en bois laminé collé comprend deux ou plusieurs segments joints entre eux et disposés, dans une direction longitudinale, l'un après l'autre.





REFERENCES CITED IN THE DESCRIPTION

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