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(56) References cited:
**EP-A1- 1 260 648 WO-A1-86/00362
US-A- 4 615 163 US-A- 5 565 257
US-A- 6 050 047**

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Description

[0001] The present invention concerns a structural element in the form of a glued wooden beam with prestressed reinforcement, wherein the glued wooden beam has a substantially rectangular cross section, and wherein a load-bearing top surface corresponds to a first short edge of the cross section and a bottom surface opposite of the top surface, to a second short edge of the cross section.

[0002] The invention concerns also a method for reinforcing a glued wooden beam with prestressed reinforcement, wherein the glued wooden beam has a substantially rectangular cross section, wherein a load-bearing top surface corresponds to a first short edge of the cross section and a bottom surface opposite of the top surface to a second short edge of the cross section

[0003] Laminated glued wooden beams have been increasingly used in modern structural engineering, beyond all as load-carrying elements, particularly with large spans; they have i.a. successfully been provided as load-carrying beams for ceiling structures in large rooms, e.g. hall buildings. Generally such laminated wooden beams have been made by joining, for instance by gluing, a number of subelements or lamellas in the form of relatively thin wooden elements and substantially of same form and dimension. The beam is thereby built to a desired web height and will usually in regard of structural considerations be formed with a rectangular cross section, the large side edge of the rectangle then constituting the web height of the beam. This contributes to providing the beam with the desired bending strength, i.e. that the beam can carry a relatively large load without sagging when used as load-carrying element in ceiling structures with large span. The ceiling beams themselves may constitute relatively small part of the load, while the weight of the beam itself shall increase with the span. The bending strength of the beam can now be increased by increasing the web height while the thickness of the beam, i.e. the length of the short edges of the cross section can be kept unchanged. Even if this shall allow relatively large spans, it has the disadvantage that a large web height in any case is a problem, particularly from an architectural point of view, and it also results in a relatively large consumption of materials. It is hence desirable to increase the bending strength of a laminated glued wooden beam without this being accompanied by a corresponding increase of the web height.

[0004] As an alternative to a load-carrying structure with laminated glued wooden beams it is common to employ steel beams or light metal beams. The latter has a much lower load-carrying capacity than the former and both will have a weight which relative to laminated glued wooden beams is not substantially better. The advantage is of course that web height of steel beams or light metal beams can be made considerably smaller. An alternative is reinforced and prestressed concrete beams, but also here high weight implies a substantial disadvantage, and reinforcing elements or prestressed elements can under special conditions be prone to corrosion.

[0005] All in all laminated glued wooden beams hence under a number of circumstances and for a number of applications can appear as particularly advantageous structural elements. Not only can they be dimensioned to endure bending loads which are comparable to the capacity of corresponding steel and metal structures, but they have at the same time a relatively much lower weight. Additionally glued wooden beams have generally a good fire resistance, while for instance steel beams will soften when red hot, i.e. at temperatures from about 550° and upwards, and lose their load-carrying capacity, something which will lead to failure and collapse so to say instantaneously. The load-carrying capacity of glued wooden beams on the whole shall decrease with the degree of through-burning which when using suitable impregnation and processing of the wooden materials would take place slowly, such that no failure of the beam will occur until the through-burning has progressed so far that the load exceeds the load-carrying capacity, given that through-burning to some extent takes place uniformly and distributed over the span.

[0006] In order to reduce the web height of the laminated wooden beams and hence the material consumption without reducing rigidity or bending strength it has been proposed to reinforce the beam. When it is considered that a loaded wooden beam is subjected to compressional forces on the load-carrying top surface and that these compressional forces propagate through the beam web and decrease to zero near the centre of the beam, while the beam therefrom and to the bottom side is subjected to increasing tensional stresses, it will be evident that the comparatively large part of the web height contributes to the load relief in relatively lesser degree. In other words, in a glued laminated wooden beam it is the lamellas which are provided nearest to respectively the top surface and the bottom surface of the beam that are subjected to the largest loads in the form of compressional and tensional forces respectively.

[0007] A laminated wooden beam according to prior art is shown in side view in fig. 1a and in cross section in fig. 1b. The beam is formed by a plurality of joined, for instance by gluing, thin identical lamellas 1' of which the top and bottom lamellas are specially indicated. The lamellas are building the beam with the desired aspect ratio. Usually the aspect ratio will be large with the intention of increasing the rigidity of the beam.

[0008] From EP patent No. 0 187 158 (= WO 8600362 A) there is known a laminated glued wooden beam which on its upper side has been provided with a reinforcing element in the form of a lamella of the same form and extension as the beam itself. Fig. 2a shows the prior art beam 1 prestressed and being provided with a non-prestressed reinforcing element 2. In fig. 2b the beam is shown relieved and with the reinforcing element 2 prestressed. The direction of the forces is in the shown case indicated by arrows. This reinforcing element 2 is preferably being made with a material

which provides the beam 1 with the desired increased bending strength, for instance steel. Several such reinforcing lamellas .2' can be used as shown in side view in fig. 2c and in cross section in fig. 2d. Before the reinforcing element 2 is mounted, the beam 1 is prestressed from the bottom side as shown in fig. 1b. The beam 1 will now be prestressed in compression at the bottom side and in tension on the upper side, but these stresses of course decrease towards zero at the center of the beam. The reinforcing element 2 is now mounted on the upper side of the beam with suitable means. These may e.g. be special mounting elements 3 provided as shown in fig. 2e or in case the reinforcing element has a U-profile, as shown in fig. 2f, wherein the mounting elements 3 secure the reinforcing element 2 across the beam 1. Alternatively the reinforcing element also can be mounted in a different manner, for instance by gluing. Additionally the reinforcing element 2 can be provided with one or more flanges 2a as shown in fig. 2g, as these flanges 2a are mating into suitable formed grooves in the laminated glued wooden beam 1 and the reinforcing element 2 is then preferably being mounted by gluing. Finally the reinforcing element 2 can be made in the form of one or more parallel bars which have been mounted onto the beam's surface as shown in fig. 2h, in this case in a recess 5.

[0009] When the beam 1 is relieved, the tensional prestress is transferred to the reinforcing element as compressional stresses and the intention is thus achieved, viz. forming a beam which provides the desired bending strength with the use of a suitably prestressed reinforcement. Alternatively the beam can also be made with a single reinforcing element or several reinforcing elements on the bottom side. A reinforcing element of this kind is mounted before or after the prestressing of the beam and will then in the latter case as disclosed in the above-mentioned patent publication, not prestress the beam 1 unless mounting and fastening of this reinforcing element as indicated take place by particular measures.

[0010] Even though reinforcement made according to EP patent No.0187 158 contributes to provide the desired result with regard to the increased bending strength, the proposed solution nevertheless comports a number of disadvantages. Reinforcing elements in the form of steel contribute in a detrimental manner to increase the weight of the beam and will additionally in case of fire be liable to soften when red hot, such that the reinforcing effect is lost, and it will then only be the wooden beam alone that has to resist and take up the load. A further disadvantage is that the reinforcing element or elements must be fastened by particular mounting elements, e.g. bolts 3 as shown in fig. 2e and fig. 2f. Mounting elements in the form of bolts can reduce the strength of the material and mounting holes or through-going mountings can additionally generate stress concentrators which are particularly unfortunate if the beam is subjected to different or variable loads. When fastening by gluing or casting it must respectively be used glue which provides a very good adhesion between a reinforcing element of metal and the wood, which may be problematic, or a suitable matrix, for instance in the form of synthetic resin which may lead to similar problems. Both glue and synthetic resin can melt or soften at increased temperatures such that the reinforcing elements separate or loosen from the beam.

[0011] It must also be mentioned that attempts have been made in the art to provide a reinforcement of an already prestressed wooden beam, by mounting additional wooden lamellas, e.g. on the convex top surface of the beam. These will then be not prestressed and of course be prestressed in compression after the beam has been separated from a clamping device and relieved. These extra reinforcing elements in the form of one or more prestressed wooden lamellas are, however, problematic as they preferably are mounted in the same manner as the remaining lamellas of the beam and the fastening means which for instance may be glue, need not be compatible with tensional stresses which are transferred to the lamellas in the form of compressional stresses. As these stresses also will vary over the portion of the web height of the beam which is occupied by these reinforcing lamellas, it may be a danger of the delamination in the relieving process, and further it is also a problem that the wooden material is deformed under compression, something which shall contribute to reduce the strength of the reinforcement further.

[0012] A general problem in prior art is that the reinforcing element must be provided with the same curvature as the prestressed beam. This implies that the reinforcing elements must be preformed, for instance in separate steps in the manufacturing process, whether they are steel or wood, and care must in addition be taken that these steps do not generate stresses in the preformed reinforcing element; possibly that it must be relieved by suitable measures.

[0013] Hence it will be desirable to provide a glued wooden beam which gives a desired high bending strength and with reduced material consumption even for large spans and without prestressing and reinforcing the beam being too complicated.

[0014] It is thus a first object of the present invention to provide a reinforced glued wooden beam wherein the reinforcement can be mounted on the prestressed glued wooden beam without particular means for mounting or joining.

[0015] It is a second object of the present invention to provide a reinforced glued wooden beam with reduced material consumption and weight by decreasing the total web height of the beam relative to an unreinforced wooden beam with the same bending strength.

[0016] It is a third object of the present invention to provide a reinforced glued wooden beam where the reinforcement can be integrated in the beam profile.

[0017] It is a fourth object of the present invention to provide a reinforced glued wooden beam wherein the weight of the beam before and after the reinforcing substantially remains unchanged.

[0018] The above-mentioned objects as well as further features and advantages are achieved with a glued wooden

beam according to the present invention which is characterized in that at least the top surface of the beam has been provided with at least one reinforcing element prestressed in compression and respectively located integral with the beam in one or more longitudinal grooves which extend parallel to the side edge of the beam and preferably over the whole length of the beam, said at least one reinforcing element initially being provided unstressed in a groove and formed by a cast reinforcing moulding compound while, the glued wooden beam resides in a state wherein it is prestressed in a cross direction towards the top surface, whereafter the reinforcing moulding compound after casting is hardened and then prestressed in compression by relieving the glued wooden beam, and that the reinforcing moulding compound after hardening and prestressing is flush with the beam surface and forms said at least one reinforcing element with a specific precompression which exceeds an expected or specific compressional load.

[0019] The above-mentioned objects as well as other features and advantages are also achieved with a method which according to the present invention is characterized by forming one or more longitudinal grooves at least in the top surface, said grooves extending parallel with the side edges of the beam and being preferably formed over the whole length of the beam, prestressing the beam in the cross direction from the bottom surface and towards the top surface, filling the groove or grooves with a mouldable and hardenable reinforcing moulding compound and keeping the beam prestressed until the reinforcing moulding compound has hardened, whereafter the beam is relieved and the reinforcing moulding compound is prestressed in compression such that the reinforcing moulding compound forms at least one reinforcing element contained in the beam and prestressed in compression.

[0020] The invention shall now be explained in more detail in connection with exemplary preferred embodiments with reference to the accompanying drawing figures, of which

fig. 1a and 1 b respectively show a side view and cross section of a laminated wooden beam according to prior art, as already mentioned,

fig. 2 a laminated wooden beam according to prior art and provided with a mounted reinforcing element and prestressed in the arrow direction, as already mentioned,

fig. 2b the reinforced laminated wooden beam in fig. 2a, after relieving with the mounted reinforcing element prestressed in compression as already mentioned,

fig. 2c another embodiment of the beam in fig. 2a,

fig. 2d the beam in fig. 2c in cross section,

fig. 2e-2h various methods for mounting a reinforcing element to the beam in fig. 2a as already mentioned,

fig. 3a a side view of an unstressed laminated wooden beam according to the invention,

fig. 3b and 3c cross sections of the beam in fig. 3a, and respectively with one or more longitudinal grooves in the top surface,

fig. 3d and 3a further cross sections of the beam in fig. 3a and with longitudinal grooves with different profiles,

fig. 4a the beam in fig. 3a mounted in a prestressing device,

fig. 4b the beam in fig. 3a prestressed in the prestressing device in fig. 4a,

fig. 4c the beam in fig. 3a relieved and being provided with a prestressed reinforcing element,

fig. 4d a cross section through the beam in fig. 4c,

fig. 5a a side view and in perspective an unreinforced laminated wooden beam (i) according to prior art compared with a reinforced laminated wooden beam (ii) according to the present invention, the latter showing a reduced web height and hence a lower specific weight for the same length,

fig. 5b in side view respectively an unreinforced laminated wooden beam (i) according to prior art compared with a reinforced laminated wooden beam (ii) according to the present invention with the same web height but with a substantially increased length compared to the unreinforced beam,

fig. 6a in side view an example of the beam according to the present invention after prestressing and placing of the reinforcement, but with a retained residual stress,

fig. 6b the same beam as in fig. 6a, but now subjected to a load corresponding to the residual stress,

fig. 7a another embodiment of a reinforced beam according to the present invention,

fig. 7b a cross section through the beam in fig. 6a,

fig. 7c the beam in fig. 7a prestressed in the direction of the arrow,

fig. 7d the beam locked in a clamping means and prestressed,

fig. 7e the same beam as in fig. 7d, but now rotated 180° about the longitudinal axis in the clamping means such that the concave side is up-turned, and

fig. 8a a side view a beam reinforced on both sides according to the present invention and under load and wherein the arrows indicate the directions of load and stress vectors, and

fig.8b a cross section through the beam in fig. 8a.

[0021] The figures 1a and 1b as well as the figures 2a-2h have already been mentioned in the introduction in connection with the discussion of prior art.

[0022] The present invention shall now be described in more detail. Fig. 3a shows a laminated unprestressed wooden beam. The separate lamellas which are building the beam 6 into an element with a large aspect ratio are not shown here, but they will basically correspond to those of the beam 1 according to prior art as shown in fig. 1a.

[0023] In fig. 3a there is by stitched line indicated a longitudinal groove 8 formed in the surface of the beam 6 in fig. 3a, Fig. 3b shows a cross section therethrough and with the longitudinal groove 8 made with a triangular profile. Fig. 3c shows a corresponding cross section, but here the top surface of the beam has been provided with two longitudinal grooves with the same profile as in fig. 3b. These grooves extend a small distance into the beam, e.g. to 20% of the web height of the beam.

[0024] It is to be understood that the grooves 8 wherein the reinforcing moulding compound is provided can have different profiles and e.g. need not be made as shown in fig. 3b or 3c and consequently neither need to be triangular, even though this is preferred, and then particularly an equilateral triangle or an equal-sided triangle with short side in the top surface of the beam. The groove or grooves 8 can also as shown in fig. 3b be formed as a circular segment wherein the cord of the circle segment lies in the top surface, and it is then at most equal to diameter, i.e. with the groove having the cross section of a semicircle. Further the cross section of the groove also can be as shown in fig. 3e, namely a polygonal segment with diagonal in the top surface and then such that the diagonal preferably is the largest diagonal of the polygon.

[0025] In fig. 4a the beam 6 in fig. 3a provided with longitudinal grooves 8 and shown now clamped in a prestressing device. It can for instance be made with a rail 9 which carries three moveable slides 10₁ - 10₃. The first slide 10₁ is provided with a hydraulic piston means or jack and located between two further movable slides 10₂, 10₃. These two slides 10₂, 10₃ each carries a clamping means 12, which may be used for locking the beam ends to the slides 10₂, 10₃ as shown in fig. 4a. The first slide 10₁ is placed midway under the beam 6 which extends parallel with and vertically above the rail 9. The piston 11 on the slide 10₁ is now moved to the bottom surface of the beam at the mid-point thereof and then is further extended such that the beam 6 is prestressed as shown in fig. 4b and with the sagitta 4 as indicated. In the longitudinal groove or grooves 8 as shown in cross section in figs. 3b-3e the reinforcing moulding compound is now applied in the form of a thick-floating liquid or mouldable material which is placed by casting in the groove or grooves 8 until it has or they have been filled and the surface of the reinforcing moulding compound is approximately flush with the top surface of the beam. The reinforcing moulding compound will now set and adhere to the side surface of the groove or grooves 8 in the prestressed beam. The reinforcing moulding compound is preferably made of a hardenable material and then a hardenable composite material, of which more in the following. After the reinforcing moulding compound has hardened and set with a secure attachment to the beam 6 in the groove 8, the beam 6 is relieved by lowering the piston 11 and the beam is now unlocked from the clamping means 12. The upper side of the beam 6 which is prestressed in tension shall now be approximately relieved or normalized such that the tensional stress decreases to zero, while the bottom surface of the beam which has been prestressed in compression, similarly is relieved to approximately zero stress. The tensional stresses will during the relieving process be taken up by the hardened reinforcing moulding compound in the groove or grooves 8 and transferred thereto as compressional stresses. If it is supposed that the reinforcing moulding compound 7 to some extent is elastic, it will hence in the moment when the beam 6 as shown

in 4c essentially is in an unstressed condition, be maximally compressed and hence prestressed in compression. The reinforcement can thus be regarded as an inverse analogy to the use of stress reinforcement in the concrete. In the latter case the reinforcement is prestressed in tension, the concrete is poured around and the reinforcement is bonded thereto and together they form the structural element which is to be reinforced. When the tension of the reinforcement is removed, the tensional stresses in the reinforcement are transferred to the concrete and prestress it in compression and hence provide a concrete element with increased compressional strength relative to an unstressed and unreinforced concrete element. In the present case and according to the present invention it is the structural element itself, namely the laminated wooden beam 6 which is prestressed and the unstressed reinforcing material in the form of reinforcing moulding compound is provided, for instance by pouring in a thick-flowing or mouldable condition into the groove or grooves 8 provided therefore and hardened, whereafter the prestress of the wooden beam is relieved and the tensional stresses on the convex side thereof is transferred as compressional stresses to the reinforcing moulding compound in the groove 8.

[0026] In a structural element of this kind the bending strength can be increased in a substantial degree given that a side surface which comprises the reinforcing element is subjected to compressional load, i.e. pressure forces. As a result the aspect ratio of the beam 6 can be reduced for the same span as shown in fig. 5a compared with that of an unreinforced beam. Correspondingly can, if the same aspect ratio is retained, the laminated and reinforced wooden beam 6 according to the invention and as shown in fig. 5b be made with a considerably larger span, e.g. up to 50% longer than a corresponding unreinforced beam. For the same span there is hence according to the present invention achieved a reduced consumption of materials and a correspondingly reduced specific weight for a given span, but alternatively can the same consumption of material and the same specific weight provide a substantially increase in the span.

[0027] Considering the reinforcing moulding compound it is preferably a hardenable composite material, and in that connection preferably at least one component of the composite material is a bonding agent and one or more additional components can be a reinforcing additive. Typically the reinforcing moulding compound can be a hardenable polymer and consist of a mixture of one or more hardenable polymers with the desired properties, while a reinforcing additive of the polymer preferably then can be present in the form of fibres such that the reinforcing moulding compound is a fibre-reinforced composite material with a polymer as the hardenable bonding agent and for instance glass fibres as reinforcing additive. Alternatively the reinforcing moulding compound can also be a ceramic material, and this ceramic material could for instance be sprayed or cast in the groove or grooves 8 with the use of a reinforcing additive which preferably could consist of fibres. An example of such fibres may be carbon fibres or ceramic fibres for instance formed of oxide, nitrides or borides or inorganic material, or possibly also organic fibres.

[0028] It can be advantageous that the top surface of the beam where for instance in structural conditions a load is exerted is coated with a protective layer. The protective layer can consist of a suitable particularly hard or wear-resistant material which either is sprayed on or applied by blading. If it is the case that the top surface of the beam is exposed in structural applications of the beam according to the invention, the layer can further advantageously be formed of fire-retardant material or it may consist of wear resistant and fire retardant material. The latter can be of importance if an organic reinforcing moulding compound is used, e.g. based on polymer, and hence contribute to the beam according to the invention retaining its bending strength in case of fire. In that connection it is to be remarked that when there is a danger that the structure may be subjected to extremely high temperatures, it shall under any circumstance be an advantage if the reinforcing moulding compound can be formed of material that is fire-retardant in itself or has a high melting point, something which is achieved with a large number of inorganic ceramic materials, and with the use of ceramic fibres as reinforcing additive. Generally also a surface layer which covers an otherwise exposed surface layer where the reinforcing element 7 has been provided, has under certain conditions, for instance as used in buildings, an esthetical aspect - the reinforcement is covered.

[0029] Usually the reinforced beam after stress-relieving and with the reinforcement prestressed in compression, will be plan in the longitudinal direction, but there is nothing to prevent a tuning of the properties of the reinforcing moulding compound after hardening such that the stresses exerted on the unreinforced beam in the prestressing do not become zero, but are left as residual stresses in the beam. This is shown in fig. 6a, where the beam after the relieving process still has a small sagitta Δh which much less than the sagitta h during the prestressing. The compressional properties of the reinforcing moulding compound are such that a further relief will not take place. Simultaneously these residual stresses in the beam and hence also the sagitta h are tuned to an estimated or computed structural load, such that the beam after mounting as a load-bearing structural element now will attain a plan configuration in the longitudinal direction as shown in fig. 6b. Essentially shall thereby the residual stresses in the beam be equalized simultaneously, while the compressional stress in the reinforcement maintains the bending strength and the pressure loads as shown by the arrows against the top surface of the beam are balanced. The forces that are present in the support point of the beam (said beam in the present case is regarded as supported with a free span between the beam ends) are shown with arrows against the bottom surface of the beam.

[0030] In another advantageous embodiment of the reinforced and laminated wooden beam according the invention

as shown in fig. 7a, the beam 6 can be provided with one or more longitudinal grooves 8, 8' both in the top and bottom surface, such as can be seen from the cross section in fig. 7b. The grooves 8, 8' can have a profile as shown in one of the figures 3b-3e and additionally be of different form respectively in the top and bottom surfaces of the beam or mutually. Regardless, it is to be understood that as in the first embodiment the number and profile of the grooves may be varied as desired. In fig. 7c the beam is shown prestressed and with reinforcement 7 in the grooves. As before, the beam 6 is placed in a prestressing device which basically can be corresponding to the one shown in fig. 4a. The beam 6 is then prestressed in the same manner as before, by for instance using a jack or hydraulic piston 11 against the bottom surface of the beam as shown in fig. 7d, and the groove or grooves 8 on the concave top surface of the beam are now filled with a reinforcing moulding compound which is set and hardened. Correspondingly also reinforcing material can be filled in grooves 8' in the bottom surface of the beam. In order to achieve this a special embodiment of the prestressing device is required and it is not discussed in detail here, but shall be based on that while the beam is prestressed between moveable clamping means 12 on the slides 10₂, 10₃, these are locked to the slides 10₂, 10₃ and the hydraulic piston 11 removed, while the prestress is maintained and the reinforcing moulding compound provided in the groove or grooves 8 on the bottom side. This could in principle take place from the underside, but it shall be most advantageous if the beam is rotated 180° such that the concave bottom surface is turned upwards, something which shall ease the placement of reinforcing moulding compound. This is shown in fig. 7e. This implies that the clamping means 12 must be locked in jigs 13 which can be translated on and locked to the slides 10₂, 10₃. Simultaneously the clamping means 12 must be mounted rotatable about longitudinal axis of the beam in the jigs 13. After relieving the prestress and releasing the beam 6 from the prestressing device, something which can take place after the reinforcing moulding compound in all grooves both on the top and bottom surface of the beam has set and hardened, the prestressing forces, i.e. both the tensional and compressional stresses that were applied to the beam 6 in the prestressing operation, are relieved and respectively transferred to the reinforcing moulding compound in the groove or grooves 8 in the top surface as compressional stress and to the reinforcing material in the groove or grooves 8' in the bottom surface as tensional stress. The beam 6 as shown in fig. 8a in side view and fig. 8b in cross section thereby become symmetrically reinforced in prestress and the tensional and compressional stresses of the reinforcement balance each other in the static and unloaded condition.

[0031] Used as a structural element, for instance as a girder in a ceiling structure or in order to support a load, the beam top surface which is convex during the prestressing is loaded as shown in fig. 8a with arrows perpendicularly to the top surface. The load is counterbalanced by the compressional stresses as indicated by horizontal arrows above the beam in the prestressed reinforcing moulding compound in the groove or grooves in the top surface of the beam. Correspondingly the load will induce tensional stresses in the opposite portion of the beam, i.e. induce tensional stresses in an increasing degree from the horizontal plane through the longitudinal axis of the beam on these tensional stresses attaining a maximum at the beam surface of the bottom side. However, here the reinforcing moulding compound has been provided a groove or grooves 8 on the bottom surface of the beam prestressed in tension and due to this symmetrically provided dual prestressed reinforcement a further improvement of both the bending strength of the beam is attained, something which can provide a further reduction of the web height compared with the beam with one-sided reinforcement prestressed in compression, but also a corresponding increase in the possible span.

[0032] It shall be briefly mentioned that in prior art there is known to provide unprestressed reinforcing elements on the concave bottom surface of the beam, but this mounting of reinforcing elements must take place before the beam is prestressed and will hence not have the same effect as a beam which has been symmetrically reinforced with prestressed reinforcement respectively both in the top and bottom surface of the beam, such that the reinforcing stresses in the static case are symmetrically balanced around the plane parallel to the top and bottom surfaces and in the central longitudinal axis of the beam and then respectively in compression and tension.

[0033] In addition to providing the desired improvement of the bending strength of laminated wooden beams, a reinforced and laminated wooden beam with prestressed reinforcement made according to the present invention shall offer a large number of advantages. Compared with the use of reinforcing elements of for instance steel or metals, the use of a reinforcing moulding compound according to the present invention shall result in a far smaller specific weight with retainment of the desired strength properties, while the aspect ratio can be reduced or alternatively the span increased with up to 50%. In addition it shall also be far easier to place the reinforcing moulding compound, as it as used has the desired good adhesion properties in conjunction with the wood material, such that there is no need for particular joining means for the reinforcing moulding compound.

[0034] Even if the reinforcing moulding compound in the grooves will be exposed when the beam according to the present invention is used as a structural element, the esthetical aspect can be handled by suitable surface treatment which in addition to protective and fire-retardant coatings can be provided by paint or coating materials which have no other function than the purely esthetical one.

[0035] The use of a castable or mouldable reinforcing moulding compound for the reinforcing elements also make any preforming or relieving thereof before they are mounted quite unnecessary, in contrast with the prior art wherein such operations are both problematic and cost-increasing.

Claims

- 5 1. A structural element in the form of a glued wooden beam (6) with prestressed reinforcement, wherein the glued wooden beam (6) has a substantially rectangular cross section, and wherein a load-bearing top surface corresponds to a first short edge of the cross section and a bottom surface opposite of the top surface, to a second short edge of the cross section,
characterized in that at least the top surface of the beam (6) has been provided with at least one reinforcing element (7) prestressed in compression and respectively located integral with the beam in one or more longitudinal grooves (8) which extend parallel to the side edge of the beam and preferably over the whole length of the beam,
10 said at least one reinforcing element (7) initially being provided unstressed in a groove (8) and formed by a cast reinforcing moulding compound while the glued wooden beam resides in a state wherein it is prestressed in a cross direction towards the top surface, whereafter the reinforcing moulding compound after casting is hardened and then prestressed in compression by relieving the glued wooden beam (6), and that the reinforcing moulding compound after hardening and prestressing is flush with the beam surface and forms said at least one reinforcing element (7)
15 with a specific precompression which exceeds an expected or specific compressional load.
2. A structural element according to claim 1, **characterized in that** the cross section of the groove or grooves (8) forms a triangle, the triangle preferably being an equilateral triangle with the hypotenuse in the top surface.
- 20 3. A structural element according to claim 1, **characterized in that** the cross section of the groove or grooves (8) forms a circular segment with the chord in the top surface, said chord at most being equal to the diameter.
4. A structural element according to claim 1, **characterized in that** the cross section of the groove or grooves (8) forms a polygonal segment with a diagonal in the top surface, said diagonal being at most equal to the largest
25 diagonal in the polygon.
5. A structural element according to claim 1, **characterized in that** the reinforcing moulding compound is a hardenable composite material.
- 30 6. A structural element according to claim 5, **characterized in that** at least a component of the composite material forms a bonding agent and one or more additional components a reinforcing additive.
7. A structural element according to claim 1, **characterized in that** the reinforcing moulding compound is a hardenable polymer.
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8. A structural element according to claim 7, **characterized in that** the hardenable polymer comprises a reinforcing additive, preferably in the form of fibers.
9. A structural element according to claim 1, **characterized in that** the reinforcing moulding compound is a ceramic material.
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10. A structural element according to claim 9, **characterized in that** the ceramic material comprises a reinforcing additive, preferably in the form of fibers and then particularly ceramic fibers.
- 45 11. A structural element according to claim 1, **characterized in that** the top surface in at least an exposed portion of the reinforcing element (7) has been coated with a protective layer.
12. A structural element according to claim 11, **characterized in that** the protective layer is formed by a fire-retardant material.
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13. A structural element according to claim 1, **characterized in that** additionally the bottom surface has been provided with one or more longitudinal grooves (8') which extend parallel with the side edges of the bottom surface and preferably over the whole length of the beam, and that the groove or grooves (8') has been filled with a reinforcing moulding compound which after hardening and relieving of the beam (6) forms at least one reinforcing element (7')
55 prestressed in tension.
14. A structural element according to claim 13, **characterized in that** the bottom surface at least over an exposed portion of the reinforcing element (7') has been coated with a protective layer, preferably of a fire-retardant material.

15. A method for reinforcing a glued wooden beam with prestressed reinforcement, wherein the glued wooden beam (6) has a substantially rectangular cross section, wherein a load-bearing top surface corresponds to a first short edge of the cross section and a bottom surface opposite of the top surface to a second short edge of the cross section and wherein the method is **characterized by** forming one or more longitudinal grooves at least in the top surface, said grooves extending parallel with the side edges of the beam and being preferably formed over the whole length of the beam, prestressing the beam in the cross direction from the bottom surface and towards the top surface, filling the groove or grooves with a mouldable and hardenable reinforcing moulding compound and keeping the beam prestressed until the reinforcing moulding compound has hardened, whereafter the beam is relieved and the reinforcing moulding compound is prestressed in compression such that the reinforcing moulding compound forms at least one reinforcing element contained in the beam and prestressed in compression.
16. A method according to claim 15, **characterized by** the groove or grooves being formed with a triangular profile.
17. A method according to claim 15, **characterized by** the groove or grooves being formed with a circular segment profile.
18. A method according to claim 15, **characterized by** the groove or grooves being formed with a polygonal segment profile.
19. A method according to claim 15, wherein more than one groove has been formed, **characterized by** the grooves being formed with different profiles.
20. A method according to claim 15, **characterized by** the reinforcing moulding compound being selected among one of the following materials, viz. hardenable composite materials, hardenable polymers and hardenable ceramic materials.
21. A method according to claim 20, **characterized by** the reinforcing moulding compound being cast or sprayed in the groove or grooves.
22. A method according to claim 20, **characterized by** adding a reinforcing agent to the reinforcing moulding compound, preferably in the form of fibers.
23. A method according to claim 15, **characterized by** clamping the beam before the prestressing, said prestressing taking place by applying a pressure to the bottom surface in the direction towards the top surface, the pressure being applied until the beam attains a determined sagitta.
24. A method according to claim 15, **characterized by** providing a fire-retardant coating over the top surface and at least in the exposed portion of the at least one reinforcing element.
25. A method according to claim 15, **characterized by** forming one or more corresponding grooves in the bottom surface of the beam and in a corresponding manner forming at least one reinforcing element contained in the beam at the bottom surface, said at least one reinforcing element similarly to the at least one in the top surface correspondingly being prestressed, but in tension.

Patentansprüche

1. Tragfähiges (Bau-)Element in Gestalt eines verleimten Holzträgers oder -balkens (6) mit Vorspannungs-Verstärkung, worin der verleimte Holzträger oder -balken (6) einen im wesentlichen rechtwinkligen Querschnitt aufweist und worin eine tragende obere Außenfläche einer ersten kurzen Kante des Querschnitts entspricht und eine bodenseitige Außenfläche, die der oberen Außenfläche gegenüber liegt, einer zweiten kurzen Kante des Querschnitts entspricht, **dadurch gekennzeichnet, dass** mindestens die obere Außenfläche des Trägers oder Balkens (6) mit mindestens einem Verstärkungselement (7) versehen (worden) ist, welches unter Druck vorgespannt wurde und integral mit dem Träger oder Balken in einer oder mehreren längs verlaufenden Vertiefungen oder Nuten (8), die sich parallel zu der Seitenkante des Trägers oder Balkens und vorzugsweise über die gesamte Länge des Trägers oder Balkens erstrecken, entsprechend angeordnet ist, wobei das mindestens eine Verstärkungselement (7) anfänglich ohne Vorspannung in einer Vertiefung oder Nut (8) bereitgestellt und durch eine Verstärkungs-Gießformmasse gebildet wurde, während sich der verleimte Holzträger oder -balken in einem Zustand befindet (befand), in welchem er in einer Querrichtung in Richtung der oberen Außenfläche vorgespannt ist (war), worauf die verstärkende Formmasse

nach dem Gießen gehärtet wird (wurde) und sodann eine Druck-Vorspannung erhält (erhielt), indem der verleimte Holzträger oder -balken (6) entspannt wird (wurde), und dass die verstärkende Formmasse nach dem Härten und dem Vorspannen bündig mit der Träger- oder Balkenoberfläche ist und das mindestens eine Verstärkungselement (7) mit einem spezifischen Vordruck (oder einer Vorstauchung) bildet, die eine erwartete oder spezifische Drucklast oder Stauchlast übersteigt.

2. Tragfähiges (Bau-)Element gemäß Anspruch 1, **dadurch gekennzeichnet, dass** der Querschnitt der Vertiefung (en) oder Nut(en) (8) ein Dreieck bildet, wobei das Dreieck vorzugsweise ein gleichseitiges Dreieck mit der Hypotenuse in der oberen Außenfläche ist.
3. Tragfähiges (Bau-)Element gemäß Anspruch 1, **dadurch gekennzeichnet, dass** der Querschnitt der Vertiefung (en) oder Nut(en) (8) einen Kreisabschnitt mit der Sehne in der oberen Außenfläche bildet, wobei die Sehne höchstens dem Durchmesser gleich ist.
4. Tragfähiges (Bau-)Element gemäß Anspruch 1, **dadurch gekennzeichnet, dass** der Querschnitt der Vertiefung (en) oder Nut(en) (8) einen Vieleck-Abschnitt mit einer Diagonale in der oberen Außenfläche bildet, wobei diese Diagonale höchstens gleich der größten Diagonale in dem Vieleck ist.
5. Tragfähiges (Bau-)Element gemäß Anspruch 1, **dadurch gekennzeichnet, dass** die verstärkende Formmasse ein härgbares Komposit- oder Verbundmaterial ist.
6. Tragfähiges (Bau-)Element gemäß Anspruch 5, **dadurch gekennzeichnet, dass** mindestens ein Bestandteil des Komposit- oder Verbundmaterials ein Bindemittel darstellt und ein oder mehrere zusätzliche Bestandteile ein Verstärkungszusatz sind.
7. Tragfähiges (Bau-)Element gemäß Anspruch 1, **dadurch gekennzeichnet, dass** die verstärkende Formmasse ein härgbares Polymer ist.
8. Tragfähiges (Bau-)Element gemäß Anspruch 7, **dadurch gekennzeichnet, dass** das härtbare Polymer einen Verstärkungszusatz aufweist, vorzugsweise in Gestalt von Fasern.
9. Tragfähiges (Bau-)Element gemäß Anspruch 1, **dadurch gekennzeichnet, dass** die verstärkende Formmasse ein keramisches Material ist.
10. Tragfähiges (Bau-)Element gemäß Anspruch 9, **dadurch gekennzeichnet, dass** das keramische Material einen Verstärkungszusatz aufweist, vorzugsweise in Gestalt von Fasern und dann insbesondere von keramischen Fasern.
11. Tragfähiges (Bau-)Element gemäß Anspruch 1, **dadurch gekennzeichnet, dass** die obere Außenfläche in mindestens einem freiliegenden Teil des Verstärkungselements (7) mit einer Schutzschicht bedeckt worden ist.
12. Tragfähiges (Bau-)Element gemäß Anspruch 11, **dadurch gekennzeichnet, dass** die Schutzschicht aus einem feuerhemmendem Material gebildet ist.
13. Tragfähiges (Bau-)Element gemäß Anspruch 1, **dadurch gekennzeichnet, dass** zusätzlich die bodenseitige Außenfläche mit einer oder mehreren Längsvertiefungen oder- nuten (8') ausgestattet ist, die sich parallel zu den Seitenkanten der bodenseitigen Außenfläche und vorzugsweise über die gesamte Länge des Trägers oder Balkens erstrecken, und dass die Vertiefung(en) oder Nut(en) (8') mit einer verstärkenden Formmasse befüllt worden ist/ sind, die nach dem Härten und Entlasten des Trägers oder Balkens (6) mindestens ein Verstärkungselement (7') bildet, das unter einer Zug-Vorspannung steht.
14. Tragfähiges (Bau-)Element gemäß Anspruch 13, **dadurch gekennzeichnet, dass** die bodenseitige Außenfläche mindestens über einen freiliegenden Teil des Verstärkungselements (7') mit einer Schutzschicht, vorzugsweise aus einem feuerhemmendem Material, bedeckt worden ist.
15. Verfahren zum Verstärken eines verleimten Holzträgers oder -balkens mit unter Vorspannung stehender Verstärkung, worin der verleimte Holzträger oder -balken (6) einen im wesentlichen rechtwinkligen Querschnitt aufweist und worin eine tragende obere Außenfläche einer ersten kurzen Kante des Querschnitts entspricht und eine bodenseitige Außenfläche, die der oberen Außenfläche gegenüber liegt, einer zweiten kurzen Kante des Querschnitts

entspricht,

und worin das Verfahren **gekennzeichnet ist durch** Ausbilden einer oder mehrerer sich in Längsrichtung erstreckender Vertiefungen oder Nuten (8) zumindest in der oberen Außenfläche, wobei sich die Vertiefungen oder Nuten parallel mit den Seitenkanten des Trägers oder Balkens erstrecken und vorzugsweise über die gesamte Länge des Balkens ausgebildet sind, Vorspannen des Trägers oder Balkens in der Querrichtung von der bodenseitigen Außenfläche und in Richtung der oberen Außenfläche, Befüllen der Vertiefung(en) oder Nut(en) mit einer formbaren und härtbaren Verstärkungs-Formmasse und Halten des Trägers oder Balkens unter Vorspannung, bis die verstärkende Formmasse gehärtet ist, worauf der Träger oder Balken entspannt wird und die verstärkende Formmasse unter einer stauchenden oder Druck-Vorspannung gerät, derart, dass die verstärkende Formmasse mindestens ein in dem Träger oder Balken aufgenommenes Verstärkungselement bildet, das unter Druck oder gestaucht vorgespannt ist.

16. Verfahren gemäß Anspruch 15, **dadurch gekennzeichnet, dass** die Vertiefung(en) oder Nut(en) mit einem Dreiecks-Profil ausgebildet sind.

17. Verfahren gemäß Anspruch 15, **dadurch gekennzeichnet, dass** die Vertiefung(en) oder Nut(en) mit einem Kreisabschnitts-Profil ausgebildet sind.

18. Verfahren gemäß Anspruch 15, **dadurch gekennzeichnet, dass** die Vertiefung(en) oder Nut(en) mit einem Vieleckabschnitts-Profil ausgebildet sind.

19. Verfahren gemäß Anspruch 15, worin mehr als eine Vertiefung oder Nut ausgebildet ist, **dadurch gekennzeichnet, dass** die Vertiefungen oder Nuten unterschiedliche Profile besitzen.

20. Verfahren gemäß Anspruch 15, **dadurch gekennzeichnet, dass** die verstärkende Formmasse unter einem der nachstehenden Materialien ausgewählt ist, nämlich härtbaren Komposit- oder Verbund-Materialien, härtbaren Polymeren und härtbaren Keramik-Materialien.

21. Verfahren gemäß Anspruch 20, **dadurch gekennzeichnet, dass** die verstärkende Formmasse in die Vertiefung(en) oder Nut(en) gegossen oder eingespritzt wird.

22. Verfahren gemäß Anspruch 20, **dadurch gekennzeichnet, dass** der verstärkenden Formmasse ein Verstärkungsmittel zugegeben wird, vorzugsweise in Gestalt von Fasern.

23. Verfahren gemäß Anspruch 15, **dadurch gekennzeichnet, dass** der Träger oder Balken vor dem Vorspannen eingespannt wird und dass das Vorspannen **dadurch** erfolgt, dass auf die bodenseitige Außenfläche ein Druck in Richtung der oberen Außenfläche aufgebracht wird, wobei der Druck aufgebracht wird, bis der Träger oder Balken eine vorbestimmte Pfeil- oder Scheitelhöhe erreicht hat.

24. Verfahren gemäß Anspruch 15, **dadurch gekennzeichnet, dass** eine feuerhemmende Beschichtung auf die obere Außenfläche und mindestens in dem freiliegenden Teil des mindestens einen Verstärkungselements aufgebracht oder vorgesehen wird.

25. Verfahren gemäß Anspruch 15, **dadurch gekennzeichnet, dass** eine oder mehrere entsprechende Vertiefungen oder Nuten in der bodenseitige Außenfläche des Trägers oder Balkens ausgebildet werden und auf entsprechende Weise mindestens ein in dem Träger oder Balken zur bodenseitigen Außenfläche hin gelegenes Verstärkungselement gebildet wird, wobei das mindestens eine Verstärkungselement dem mindestens einen in der oberen Außenfläche befindlichen ähnlich entsprechend, jedoch in Zugspannung, vorgespannt wird.

Revendications

1. Élément de structure sous la forme d'une poutre en bois collé (6) avec armature précontrainte, dans lequel la poutre en bois collé (6) a une section transversale sensiblement rectangulaire, et dans lequel une surface supérieure porteuse correspond à un premier bord court de la section transversale et une surface inférieure opposée à la surface supérieure correspondant à un second bord court de la section transversale, **caractérisé en ce qu'**au moins la surface supérieure de la poutre (6) a été pourvue d'au moins un élément de renfort (7) précontraint en compression et respectivement situé intégralement avec la poutre dans une ou plusieurs

rainures longitudinales (8) qui s'étendent parallèlement au bord latéral de la poutre et de préférence sur toute la longueur de la poutre, ledit au moins un élément de renfort (7) étant initialement fourni non précontraint dans une rainure (8) et formé par un moule et un mélange de renfort à mouler tandis que la poutre en bois collé réside dans un état où elle est précontrainte dans une direction transversale vers la surface supérieure, après quoi le mélange de renfort à mouler après moulage est durci et ensuite précontraint en compression en dégageant la poutre en bois collé (6), et **en ce que** le mélange de renfort à mouler après durcissement et précontrainte est au même niveau que la surface de la poutre et forme ledit au moins un élément de renfort (7) avec une précompression spécifique qui dépasse une charge de compression prévue ou spécifique.

2. Élément de structure selon la revendication 1, **caractérisé en ce que** la section transversale de la rainure ou des rainures (8) forme un triangle, le triangle étant de préférence un triangle équilatéral avec l'hypoténuse dans la surface supérieure.

3. Élément de structure selon la revendication 1, **caractérisé en ce que** la section transversale de la rainure ou des rainures (8) forme un segment circulaire avec la corde dans la surface supérieure, ladite corde étant tout au plus égale au diamètre.

4. Élément de structure selon la revendication 1, **caractérisé en ce que** la section transversale de la rainure ou des rainures (8) forme un segment polygonal avec une diagonale dans la surface supérieure, ladite diagonale étant tout au plus égale à la diagonale la plus large dans le polygone.

5. Élément de structure selon la revendication 1, **caractérisé en ce que** le mélange de renfort à mouler est un matériau composite durcissable.

6. Élément de structure selon la revendication 5, **caractérisé en ce qu'**au moins un composant du matériau composite forme un liant et un ou plusieurs composants supplémentaires un adjuvant de renfort.

7. Élément de structure selon la revendication 1, **caractérisé en ce que** le mélange de renfort à mouler est un polymère durcissable.

8. Élément de structure selon la revendication 7, **caractérisé en ce que** le polymère durcissable comprend un adjuvant de renfort, de préférence sous la forme de fibres.

9. Élément de structure selon la revendication 1, **caractérisé en ce que** le mélange de renfort à mouler est un matériau céramique.

10. Élément de structure selon la revendication 9, **caractérisé en ce que** le matériau céramique comprend un adjuvant de renfort, de préférence sous la forme de fibres et ensuite en particulier de fibres céramiques.

11. Élément de structure selon la revendication 1, **caractérisé en ce que** la surface supérieure dans au moins une partie exposée de l'élément de renfort (7) a été revêtue d'une pellicule protectrice.

12. Élément de structure selon la revendication 11, **caractérisé en ce que** la pellicule protectrice est formée par un matériau ignifugeant.

13. Élément de structure selon la revendication 1, **caractérisé en ce qu'**en outre la surface inférieure a été munie d'une ou de plusieurs rainures longitudinales (8') qui s'étendent parallèlement aux bords latéraux de la surface inférieure et de préférence sur toute la longueur de la poutre, et **en ce que** la rainure ou les rainures (8') ont été remplies d'un mélange de renfort à mouler qui après durcissement et dégagement de la poutre (6) forme au moins un élément de renfort (7') précontraint en tension.

14. Élément de structure selon la revendication 13, **caractérisé en ce que** la surface inférieure au moins sur une partie exposée de l'élément de renfort (7') a été revêtue d'une pellicule protectrice, de préférence d'un matériau ignifugeant.

15. Procédé destiné à renforcer une poutre en bois collé avec armature précontrainte, dans lequel la poutre en bois collé (6) a une section transversale sensiblement rectangulaire, dans lequel une surface supérieure porteuse correspond à un premier bord court de la section transversale et une surface inférieure opposée à la surface supérieure correspond à un second bord court de la section transversale et dans lequel le procédé est **caractérisé par la**

formation d'une ou de plusieurs rainures longitudinales au moins dans la surface supérieure, lesdites rainures s'étendant parallèlement aux bords latéraux de la poutre et étant de préférence formées sur toute la longueur de la poutre, précontrainant la poutre dans la direction transversale depuis la surface inférieure et vers la surface supérieure, le remplissage de la ou des rainures avec un mélange de renfort à mouler que l'on peut mouler et durcir et conservant la poutre précontrainte jusqu'au durcissement du mélange de renfort à mouler, après quoi la poutre est dégagée et le mélange de renfort à mouler est précontraint en compression de telle sorte que le mélange de renfort à mouler forme au moins un élément de renfort contenu dans la poutre et précontraint en compression.

16. Procédé selon la revendication 15, **caractérisé en ce que** la rainure ou les rainures sont formées par un profil triangulaire.

17. Procédé selon la revendication 15, **caractérisé en ce que** la rainure ou les rainures sont formées par un profil segmentaire circulaire.

18. Procédé selon la revendication 15, **caractérisé en ce que** la rainure ou les rainures sont formées par un profil segmentaire polygonal.

19. Procédé selon la revendication 15, dans lequel plus d'une rainure ont été formées, **caractérisé en ce que** les rainures sont formées par différents profils.

20. Procédé selon la revendication 15, **caractérisé en ce que** le mélange de renfort à mouler est sélectionné parmi l'un des matériaux suivants, à savoir des matériaux composites durcissables, des polymères durcissables et des céramiques durcissables.

21. Procédé selon la revendication 20, **caractérisé en ce que** le mélange de renfort à mouler est moulé ou pulvérisé dans la rainure ou les rainures.

22. Procédé selon la revendication 20, **caractérisé en ce que** l'ajout d'un agent renforçant au mélange de renfort à mouler, est de préférence sous la forme de fibres.

23. Procédé selon la revendication 15, **caractérisé en ce que** le blocage de la poutre est avant la précontrainte, ladite précontrainte se produisant en appliquant une pression sur la surface inférieure dans la direction vers la surface supérieure, la pression étant appliquée jusqu'à ce que la poutre atteigne une flèche (sagitta) déterminée.

24. Procédé selon la revendication 15, **caractérisé par** la fourniture d'un revêtement ignifugeant sur la surface supérieure et au moins dans la partie exposée du au moins un élément de renfort.

25. Procédé selon la revendication 15, **caractérisé par** la formation d'une ou de plusieurs rainures correspondantes dans la surface inférieure de la poutre et d'une manière correspondante formant au moins un élément de renfort contenu dans la poutre au niveau de la surface inférieure, ledit au moins un élément de renfort similairement à le moins un élément de renfort dans la surface supérieure étant précontraint de manière correspondante, mais en tension.

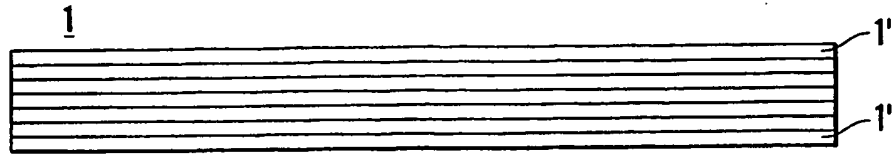


Fig. 1a (Prior Art)

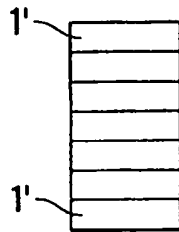


Fig. 1b (Prior Art)

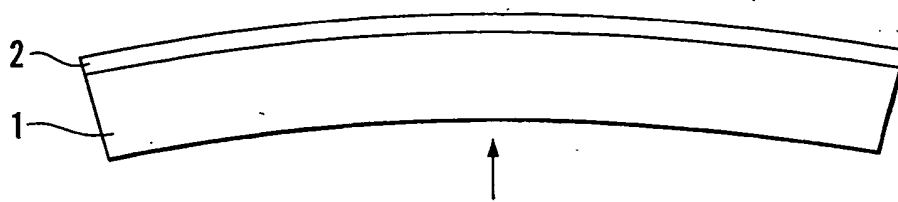


Fig. 2a (Prior Art)

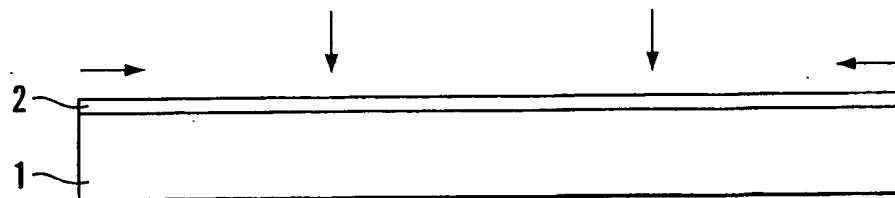


Fig. 2b (Prior Art)

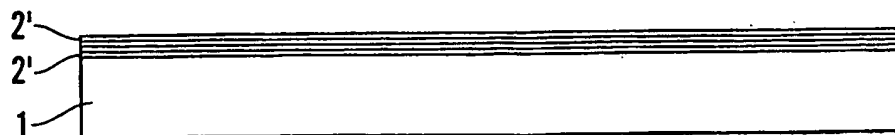


Fig. 2c (Prior Art)



Fig. 2c (Prior Art)

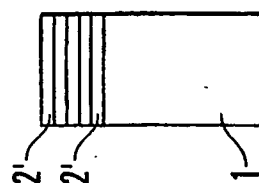


Fig. 2d
(Prior Art)

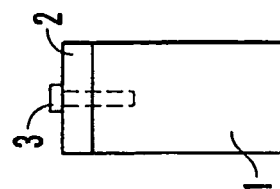


Fig. 2e
(Prior Art)

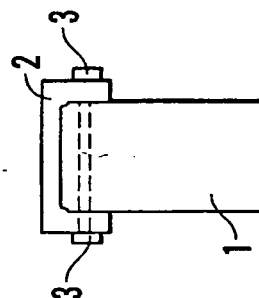


Fig. 2f
(Prior Art)

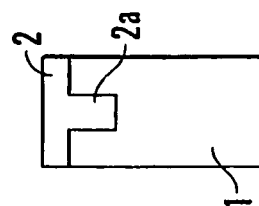


Fig. 2g
(Prior Art)

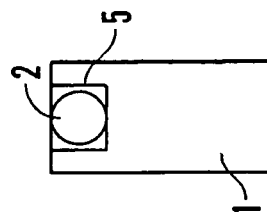


Fig. 2h
(Prior Art)

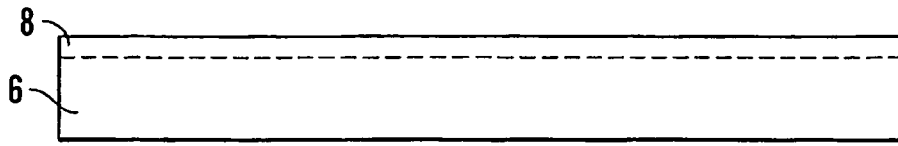


Fig. 3a

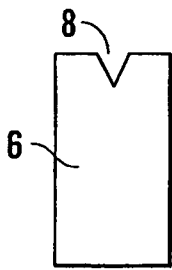


Fig. 3b

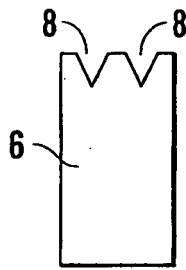


Fig. 3c

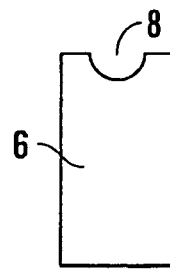


Fig. 3d

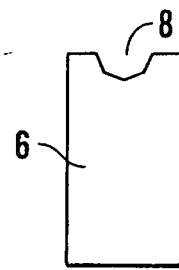


Fig. 3e

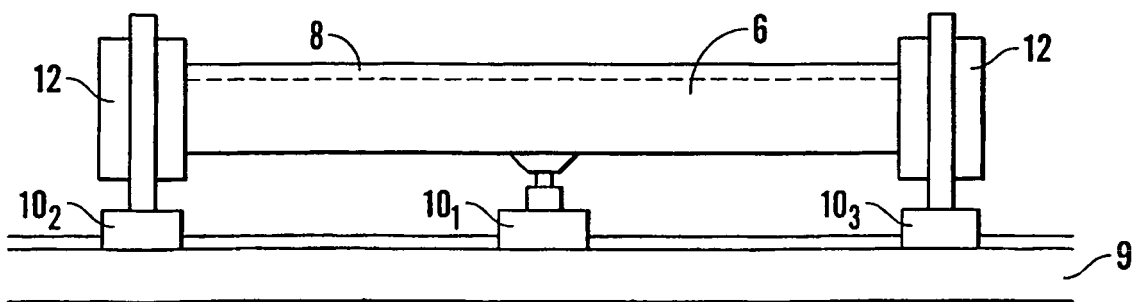


Fig. 4a

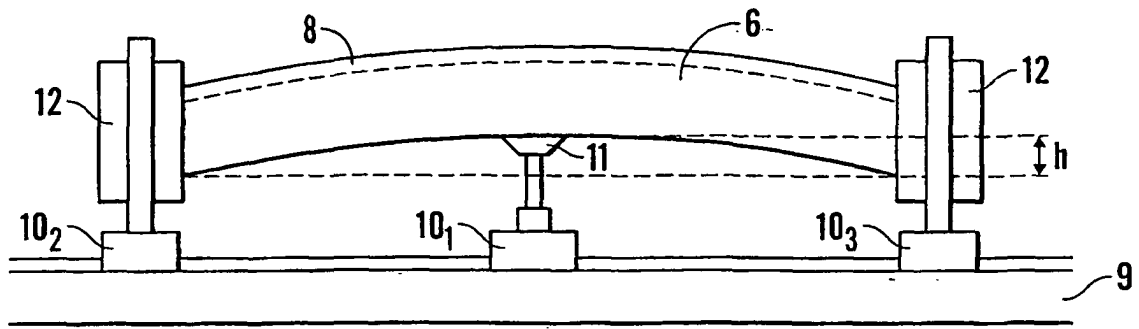


Fig. 4b

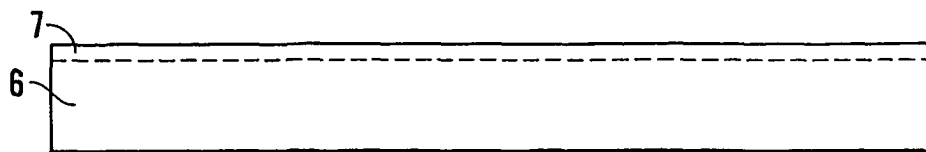


Fig. 4c

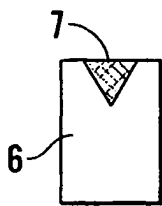
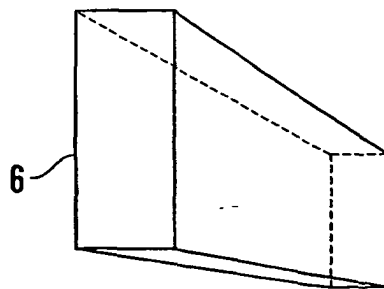
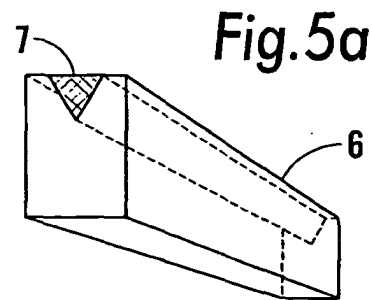


Fig. 4d



(i)

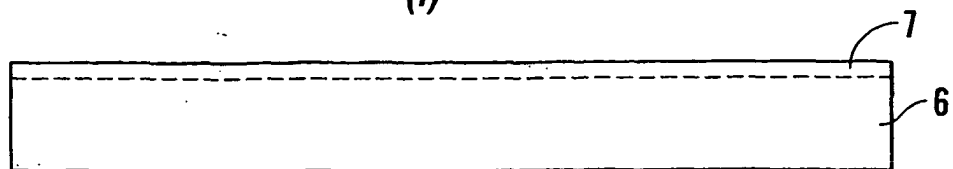


(ii)

Fig. 5a



(i)



(ii)

Fig. 5b

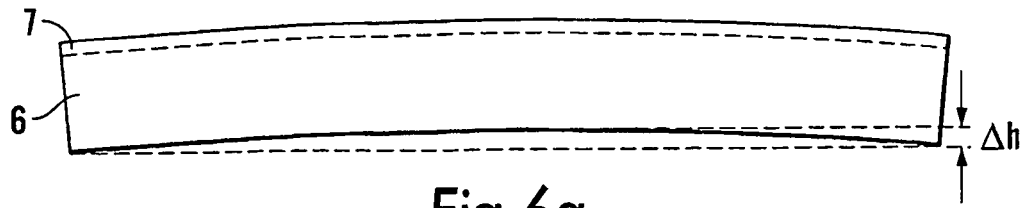


Fig. 6a

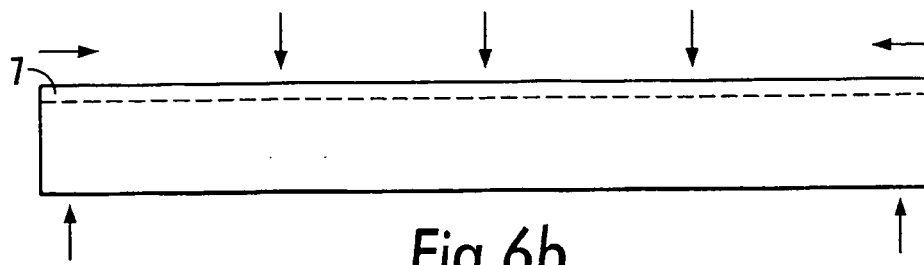


Fig. 6b

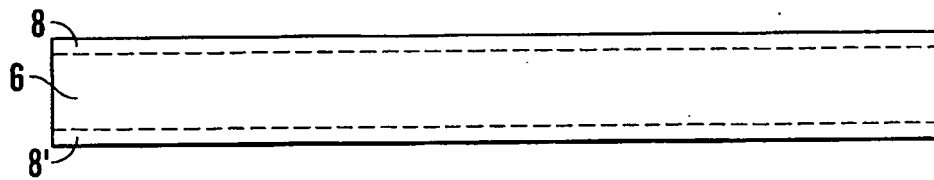


Fig. 7a

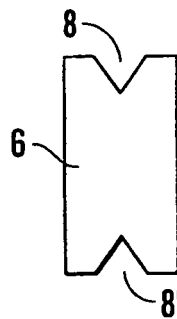


Fig. 7b

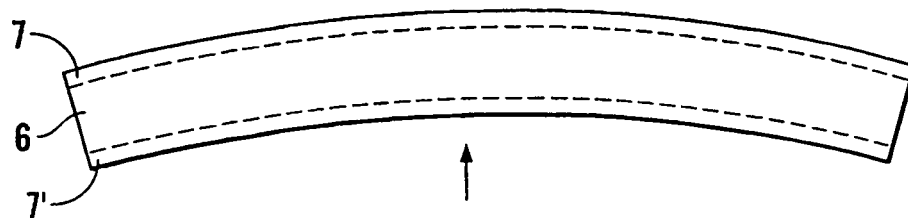


Fig. 7c

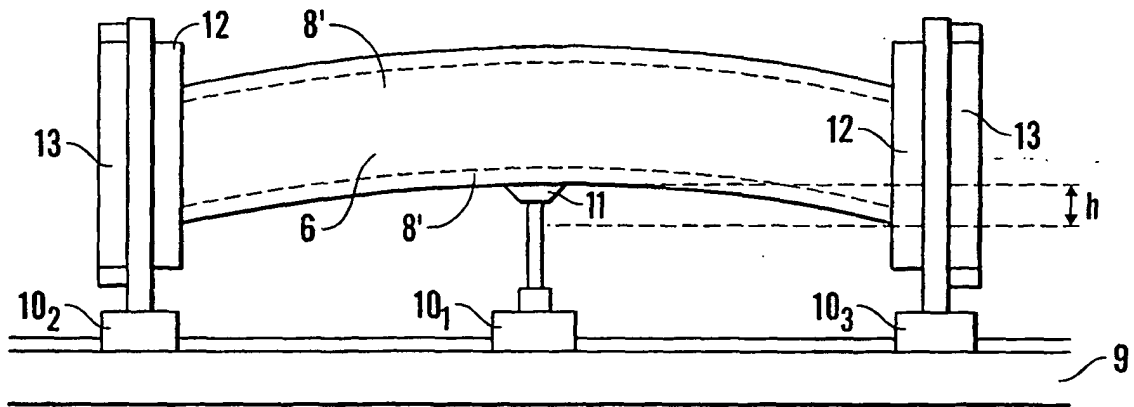


Fig. 7d

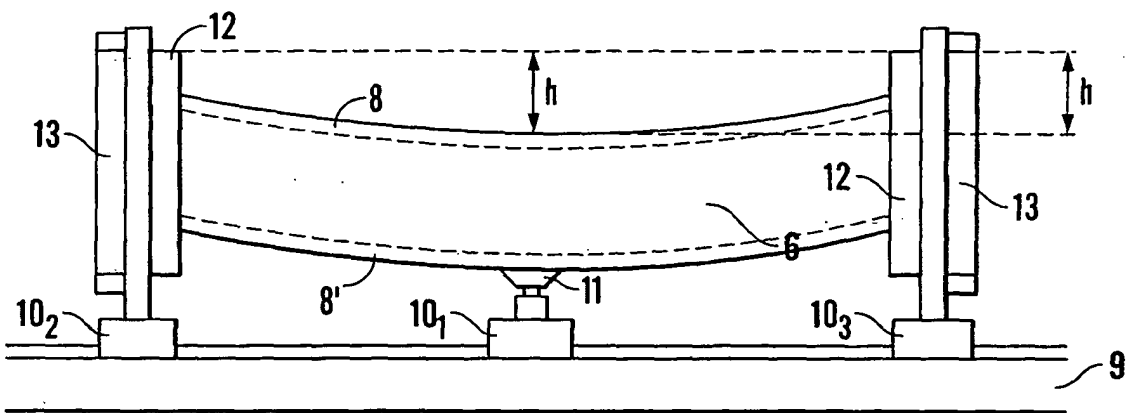


Fig. 7e

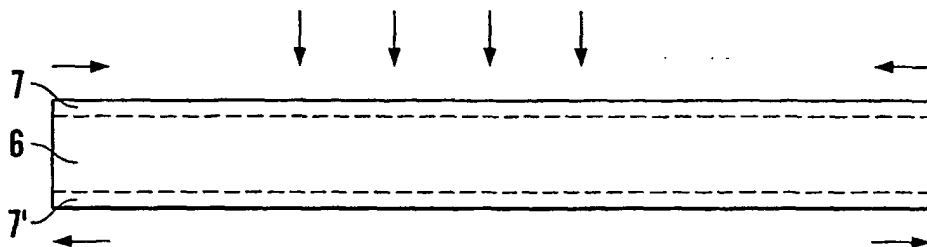


Fig. 8a

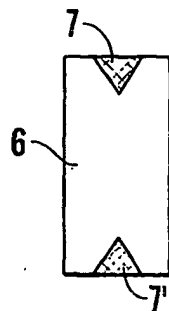


Fig. 8b