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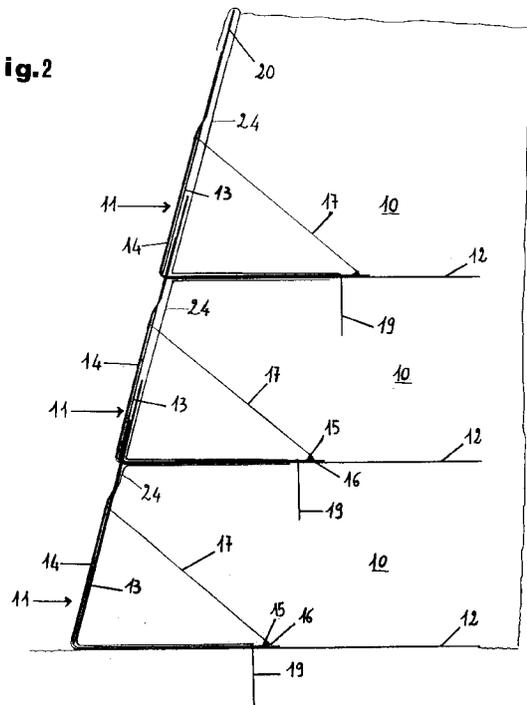
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Method for forming vegetated slopes in strengthened ground and a product obtained by such method.

A method for forming steep slopes covered with a mantle of vegetation constructed of strengthened and reinforced earth comprising the following operations :

- (a) levelling the ground,
- (b) laying a substantially horizontal layer of geocomposite material (12),
- (c) forming a reinforcing cage for a first layer of earth (10), with a plurality of uprights (14) spaced apart and with a grid (11) anchored to said uprights (14),
- (d) laying a layer of material to allow root penetration and growth on the rear surface of said grid (11),
- (e) filling the space between the geocomposite material (12) and the material covering the grid (11) with earth (10), compacting said earth (10) and forming a new flat surface at a level which allows the upper ends of said uprights (14) to project thereabove,
- (f) laying another substantially horizontal layer of geocomposite material (12),
- (g) installing a second set of uprights (14), connecting them slidably to the projecting ends of the uprights (14) of the underlying layer, and forming a further reinforcing cage for the subsequent layer of earth (10) by attaching grids (11) to the uprights,
- (h) repeating operations (d) and (e) to complete a new layer of compacted earth,
- (i) repeating operations (f), (g) and (h) so as to reach the predetermined height of the slope,
- (j) making provision for shoots to grow on the slope.

fig.2



This invention relates to a method for forming steep slopes completely covered with a mantle of vegetation in strengthened and reinforced ground, and the structure obtained using such method.

This method of forming slopes is of great importance whenever it is desired to limit the increasing destruction of the natural countryside without dispensing with the necessary supporting works for new structures, such as e.g. roads, motorways, railways or river banks, which have to be incorporated into the countryside.

As is known, where the profile of the ground is not flat, cuttings or embankments have to be provided as a foundation level for roads or railways, etc., and in both cases the foundation plane obtained has to be joined to the original surface by means of vertical walls called retaining walls or inclined surfaces known as embanked slopes. The most well-known retaining walls are those of reinforced concrete. In this method, a monolithic structure is built, and this, in addition to being expensive, also has a high and not very pleasing environmental impact. In fact, in order to construct a wall of reinforced concrete, extensive excavation has to be performed in order to construct a plane on which to set its foundations. Also, the excavations have to be very much more extensive than those strictly necessary for the finished structure in order to be able to provide for the structures behind the elevation of the wall.

Various methods of constructing slopes are known, such as e.g. slopes using gabions or slopes of earth reinforced with woven fabrics, grids or concrete members shaped to contain earth. In the first instance the structures are of the "cellular" type, consisting of rectangular members formed of zinc-coated metal mesh filled with stones of suitable mechanical properties and weight. The individual units are joined together by means of welded ties. The main disadvantage of this technique lies in finding the stony material and the high cost of its transport, which limits the use of this approach to areas close to excavations of stony material. In addition, slopes made using gabions do not produce slopes with flat surfaces and are difficult to cover with a mantle of vegetation or other plantings.

In a second instance, as illustrated in European Patent No. 197,000, slopes covered with a mantle of vegetation are obtained using woven products as a reinforcement for the ground.

The main disadvantage of this technique is that the heights of the slopes which can be constructed using this method is limited by the behaviour of the textile material used as reinforcement, when this is subjected to a high load over a long period of time.

A second disadvantage is that, with this method, it is not possible to stabilise the durability of the structure itself, and therefore it is not always accepted by the appropriate authorities for permanent structures.

The third disadvantage is that the external appearance of the slopes constructed by this means is not always aesthetically valid, especially if the slopes have to be curved, because of the excessive number of sharp edges which are apparent.

Finally a fourth disadvantage is that any subsidence of the ground in any one of the layers forming the slopes involves distortion of the metal supporting structure for the textile with consequent detachment of the textile from the underlying ground and corresponding damage.

The third instance mentioned above relates to reinforced concrete structures with earth filled spaces for planting vegetation. The main disadvantage of this technique is the limited range of vegetation which can grow, because of the fact that with reference to the slope surface the percentage occupied by reinforced concrete predominates greatly over that occupied by earth and plants have great difficulty in thriving in such an environment.

U.S. Patent No. 4,117,686 discloses reinforcement for ground areas consisting of L-shaped metal meshes where the long horizontal sides are inserted into the ground and the short sides are inclined, forming the surface of the slope. The ground behind the wall is thus subdivided into various horizontal layers which are tied together by means of the said reinforcement. Slopes obtained using this system have a surface consisting of members of a rectangular or square metal mesh, which are visible and rigidly linked together, and which are therefore also subject to deformation if the ground should subside.

A principal object of this invention is to provide a method for forming slopes of strengthened and reinforced ground, and a structure so obtained, which avoid or substantially reduce the abovementioned disadvantages of known methods and which also make it possible to cover slopes with vegetation by means of e.g. spray sowing, and to allow the vegetation to be mown either by hand or by machine.

A second object of the invention is to provide a structure which is easy to construct, is of limited weight and size for transport, and which can use any type of soil material available in situ.

In accordance with the first feature of this invention a method is provided which comprises the following operations:

- a) levelling the ground,
- b) laying a substantially horizontal layer of a geocomposite material,
- c) forming a reinforcing cage for a first layer of earth, with a plurality of uprights which are spaced apart and with a grid anchored to the said uprights,
- d) laying a layer of material which will allow roots to penetrate and grow on the rear surface of the said grid,
- e) filling the space between the geocomposite

material and the material covering said grid with earth, compacting said earth and forming a new level at a level which allows the upper ends of said uprights to project thereabove,
 f) laying another substantially horizontal layer of geocomposite material,
 g) installing a second set of uprights, connecting them slidably on the projecting ends of the uprights of the underlying layer, and forming with said grid a reinforcing cage for the subsequent layer of earth,
 h) repeating operations d) and e) to complete another layer of compacted earth,
 i) repeating operations f), g) and h) so as to achieve the predetermined height of the slope,
 i') laying a layer of finishing material at the top of the slope if appropriate,
 j) making provision for the slope to be covered with shoots.

In accordance with another aspect of this invention, a structure is provided for a reinforced soil slope obtained by the method of the invention, comprising a plurality of layers of compacted earth, each layer being retained by a reinforcing cage consisting of two horizontal layers of geocomposite material, a plurality of uprights and a plurality of curtain panels, forming a portion of the side surface of the slope, each panel being formed of a lattice grid and a sheet of material allowing root penetration and growth and held secure by the said uprights, which are anchored to the corresponding layers of earth, and in which the uprights of the upper layers are nested onto those beneath, the two sliding over each other along their own axis.

The great advantage offered by the arrangement proposed lies in the fact that uniform and/or differential settling of the ground, even if extensive, does not cause detachment of the slope surface, which remains bonded to the underlying ground.

A second advantage is that any soil can be used to construct the structure, which makes it possible to use the soil available on the site where the structure is constructed, eliminating the costs of transporting fill material.

Another advantage derives from the fact that the structure makes it possible to use strips of steel, grids or meshes anchored to uprights in such a way that the slopes have better resistance to loading, which makes it possible to construct layers of earth which are deeper than those obtained using known methods, thus substantially reducing the costs of constructing the structure, because less layers are needed for the same height through the use of the said reinforcing strips.

A further advantage derives from the fact that the structure to which this invention relates makes it possible to construct slopes of a considerable height with angles of inclination close to 90°, while known structures only permit maximum angles of inclination not

exceeding 60-65°.

Another advantage is therefore provided by the fact that given its robustness, the service life of the structure is increased and can also be calculated in a sufficiently precise manner.

A further advantage derives from the fact that with this invention it is possible to construct slopes which follow curvilinear profiles, without revealing any unaesthetic sharp edges.

The present invention will be further illustrated, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a partial axonometric view of a structure in accordance with this invention;

Fig. 2 is a view in vertical cross-section of a structure of the type in Fig. 1, but with three layers of soil instead of two;

Fig. 3 is an axonometric view of a front panel of a structure according to the invention;

Fig. 4 is an axonomic view of a "braces style" upright of the structure according to the invention;

Fig. 5 is a lateral view of a second embodiment of an upright of the structure according to the invention;

Fig. 6 is a front perspective view of the upright in the preceding figure;

Figs. 7, 8 and 9 are lateral and front views and a view from above respectively of the first piece of the upright illustrated in Figs. 5, 6 and

Figs. 10 and 11 are a side view and a front view respectively of the second piece of the upright illustrated in Figs. 5 and 6.

With reference to the figures listed above it will be noted that the structure for a slope of strengthened and reinforced ground obtained using the system according to the invention comprises a plurality of layers of compacted earth 10 retained by a containing cage 11 formed from two horizontal layers of geocomposite material 12 and a curtain panel 13 forming an inclined surface of the slope. The said curtain panel which forms a length of the lateral surface of the slope comprises a grid covered with a material 24 which allows root penetration and growth, such as e.g. a wooden mat or, as illustrated in Figure 2, a synthetic fabric. The said panel is supported by a plurality of uprights 14 which are L-shaped, with one side 14a horizontal and the other side 14b bent upwards so that the two sides form an angle between them which in the example illustrated in Figs. 1 and 2 is less than 90°, but which in other embodiments of the invention, not illustrated, may also be equal to 90°.

Said uprights 14 are anchored into those of the overlying layer of earth in such a way that they can slide along the axis of the said uprights. This allows the containment cage to follow movements of the outer wall of the earth behind when this sinks as a result of any uniform or differential settling of the ground.

Each upright, illustrated in Fig. 4, is constructed

from a rectangular strip of material, e.g. steel, of constant thickness, by being first shaped into an L with one side horizontal and one side bent upwards. The horizontal side has a tongue 15 which is partly folded upwards at its terminal end and is able to hold a bar 16 of steel which stiffens the entire cage and anchors by means of a tie rod 17 which connects the two terminal ends of the said two sides of upright 14. The horizontal side also has, again close to its terminal end, a hole 18 into which a peg 19 is inserted with the object of securing the said cage to the underlying ground. On this hole may also be fixed a steel brace 23 or grid, or electrically welded lattice, or any other member acting as a reinforcement. The latter reinforcement allows better distribution of the loads in the embankment and greater support, thus making it possible to achieve greater heights and inclinations for the slopes.

Again on the said horizontal side of upright 14, close to the bend connecting with the other side, a rectangular hole 25 is provided to provide a sliding connection between two superimposed uprights. In fact the side of each upwardly bent upright has its own terminal end 20 of a width appreciably smaller than the width of the remaining part of the said side. This is obtained by means of a sudden narrowing 21 in its width. At the same time the said end 20 is deviated in a parallel plane, but to the rear with respect to the plane of the remaining part of the said bent side 14b, by means of a second bend corresponding to the said narrowing 21. This bend allows terminal extremity 20 of the said bent side to enter into said hole 25 of a second upright which is slidably inserted on the former, maintaining the two outer surfaces of the bent sides of the superimposed uprights coplanar at the same time.

The upwardly bent side of each L-shaped upright also has a series of slots 22, distributed uniformly along the entire portion of the said side between the said two folds. The said slots 22 allow the roots of the outer mantle of vegetation to penetrate the earth behind, in such a way as to allow uniform distribution of the mantle vegetation over the entire surface of the slope.

In clay ground the friction values which occur between the contact surfaces of two superimposed uprights can be sufficiently high to prevent relative sliding between the uprights, thus hindering the structure from settling if there is differential settling of the ground. In order to overcome these disadvantages a second form of upright appropriate to a structure for a strengthened and reinforced earth slope according to this invention, which is illustrated in Figs. 5 to 11 and described below, has been provided.

This second embodiment, in which the upper slidable end of each upright is moved from the interior to the exterior of the structure, makes it possible to effect a considerable reduction in the aforesaid friction.

Each upright 14' comprises two pieces which can be attached together in a removable way, the first piece 25 being substantially L-shaped with its longer arm 25a being placed horizontally when in use and its second arm 25b being directed upwards, while the second piece 26 is substantially straight.

Both short arm 25b of first piece 25 and second piece 26 have upper terminal ends 27, 28 of a constant width which is substantially smaller than the width of the remaining portion of the piece. This end can slide within an ear 29 constructed on the outside of the lower end 30 of said second piece 26 of upright 14'.

Said ear 29 has a rectangular hole 32 which is slightly wider than the said upper terminal ends 27 and 28 and a height equal to a little more than the sum of the thicknesses of the said two ends. In this way first piece 25 and second piece 26 of each upright 14' are coupled together by fitting upper end 27 of short arm 25a of first piece 25 into the said ear provided in said second piece 26. On the other hand two uprights belonging to two superimposed layers of compacted earth are coupled together by slidably fitting upper end 28 of second piece 26 of an upright 14' of the underlying layer into the said ear of the said second piece 26 of the overlying upright. In this way the outer surfaces of the bent sides of the two superimposed uprights can slide while remaining coplanar with each other. Suitable grooves 33 located on each of members 25 and 26 at the sides of each end 27 and 28 act to guide and stabilise the coupling described above.

The horizontal arm of first piece 25 also has a hole 18', again close to its terminal end, into which a pin, which is not illustrated, can be inserted in order to secure the said cage to the underlying ground.

In the embodiment illustrated in Figs 5 to 11, the said uprights 14' are formed in a press from a rectangular strip of metal material of constant thickness and width.

The anchoring means to secure the tie bars and horizontal members of the reinforcing cage, which are not illustrated in the drawings, comprise hooks 31. The said hooks 31 are obtained by bending portions of the said pieces which are cut into a tongue shape and project behind the plane of each piece when in use. In the course of construction the tongue is first bent in a direction perpendicular to the corresponding arm and then parallel thereto. In this way there is no need for welding. One of said hooks 31 is located close to the terminal end of each of the two arms of each upright so as to permit a tie bar which is not illustrated in the drawings to be anchored.

The upper finishing material of the earth embankment may vary, depending on whether it is the site of a road or a railway, a surface which can be walked on or a grass .

Claims

1. A method for forming steep slopes covered with a mantle of vegetation constructed of strengthened and reinforced earth comprising the following operations:
 - (a) levelling the ground,
 - (b) laying a substantially horizontal layer of geocomposite material,
 - (c) forming a reinforcing cage for a first layer of earth, with a plurality of uprights spaced apart and with a grid anchored to said uprights,
 - (d) laying a layer of material to allow root penetration and growth on the rear surface of said grid,
 - (e) filling the space between the geocomposite material and the material covering the grid with earth, compacting said earth and forming a new flat surface at a level which allows the upper ends of said uprights to project thereabove,
 - (f) laying another substantially horizontal layer of geocomposite material,
 - (g) installing a second set of uprights, connecting them slidably to the projecting ends of the uprights of the underlying layer, and forming a further reinforcing cage for the subsequent layer of earth by attaching grids to the uprights,
 - (h) repeating operations (d) and (e) to complete a new layer of compacted earth,
 - (i) repeating operations (f), (g) and (h) so as to reach the predetermined height of the slope,
 - (j) making provision for shoots to grow on the slope
2. A method according to claim 1, in which operation (c) comprises: forming a reinforcing cage for a first layer of earth by means of a plurality of uprights spaced apart and a grid anchored to the said uprights, and fixing reinforcing strips which extend horizontally and perpendicular to the surface of the slope to the said uprights in the ground between one layer of earth and another.
3. A method according to claim 1 or 2, comprising the laying of a layer of finishing material at the top of the slope.
4. A structure for a slope of strengthened and reinforced earth obtained by a method according to any one of claims 1 to 3, comprising a plurality of layers of compacted earth, each layer being retained by a reinforcing cage comprising two substantially horizontal layers of geocomposite material, a plurality of uprights which are spaced apart and a plurality of curtain panels in a portion of the side surface of the slope, each panel being formed of a lattice grid and a sheet of material which will allow root penetration and growth and which is held fixedly by the said uprights, which are anchored in the corresponding layers of earth, and in which the uprights of the upper layers are slidably linked with those beneath, one sliding upon the other along its own axis.
5. A structure according to claim 4, in which each upright is L-shaped with, in use, one horizontal arm and one arm which extends in a plane parallel to the plane of the slope orientated upwards in such a way that the two arms form an angle of not more than 90° between them, in which two or more superimposed uprights are slidably connected together by engaging and guide means, and in which the said uprights are provided with means to anchor tie bars and members connecting the consecutive uprights in a given layer to render the said reinforcing cage rigid.
6. A structure according to claim 5, in which each upright has adjacent to the free end of its horizontal arm at least one hole suitable for the insertion of a fixing pin, while said guidance and sliding means comprising a through opening is provided at the other end, and in which the said second arm has a first portion of a width corresponding to the width of the horizontal arm and a second terminal portion which is appreciably less wide than the said first portion and is laid in a plane parallel to but set back from the plane in which the said first portion lies in such a way as to permit the said terminal end of the second arm to slide through the said opening of an upper upright slidably fitted from above.
7. A structure for a slope of strengthened and reinforced earth according to claim 5, in which each upright comprises two pieces which can be attached together in a removable manner, the first piece being substantially L-shaped with a longer arm located horizontally and the short upward arm parallel to the face of the slope, while the second piece is substantially straight, in which both the short arm of the first piece and the second piece have in use their upper terminal ends of a constant width which is substantially less than the width of the remaining portion of the piece, said end being capable of sliding between said guide means comprising an ear constructed on the outside of the lower end of the said second piece of upright, said ear bounding a rectangular opening of a width slightly greater than the width of said terminal upper ends and a height which is equal to a little more than the sum of the thicknesses of said two ends.

8. A structure for a slope of strengthened and reinforced earth according to claim 7, in which the first and second pieces of each upright are coupled by fitting the upper end of the short arm of the first piece into the said ear provided in said second piece, while two superimposed uprights are coupled by slidably fitting the upper end of the second piece of an upright from an underlying layer into said ear of said second piece of the overlying upright in such a way as to maintain the outer surfaces of the arms of the two superimposed uprights parallel to the face of the slope substantially in the same plane. 5
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9. A structure for a slope of strengthened and reinforced earth according to any one of claims 6 to 8, in which said uprights are constructed from a rectangular strip of material of constant thickness and width, in which said anchoring means comprise a plurality of hooks provided on both sides of the upright obtained by bending tongues which have been cut out along each arm and which are orientated parallel to the said arm, and in which one of the said hooks is located close to the terminal end of each of the two arms of each upright. 20
25
10. A structure for a slope of strengthened and reinforced earth according to any one of claims 4 to 9, in which the upwardly pointing arm of each upright has a series of slots or holes to allow roots to penetrate the ground behind, distributed uniformly along the entire portion of said visible arm on the outside of said structure. 30
35
11. A structure for a slope of strengthened and reinforced earth according to any one of claims 4 to 10, in which said layer of geocomposite material is a biocomponent obtained by combining a set of high strength monofilament polyester fibres interlaced with a structural part of woven fabric and a layer of non-woven polyester material capable of allowing water to drain, in which said geocomposite material can achieve tensile strengths in excess of 60 kN/m. 40
45
12. A structure for a slope of strengthened and reinforced earth according to any one of claims 4 to 11, in which said reinforcing strips are anchored at the terminal ends of the horizontal arms of each of said uprights and are such as to improve the strength characteristics of the ground, and in which said reinforcing strips consist of strips of steel, or grids, or electrically welded metal lattices. 50
55
13. A structure for a slope of strengthened and reinforced earth according to any one of claims 4 to 12, in which said material allowing root penetra-

tion and growth comprises an inset wooden mat and synthetic fibre which is secured to the lattice grid by the mere pressure of the earth behind.

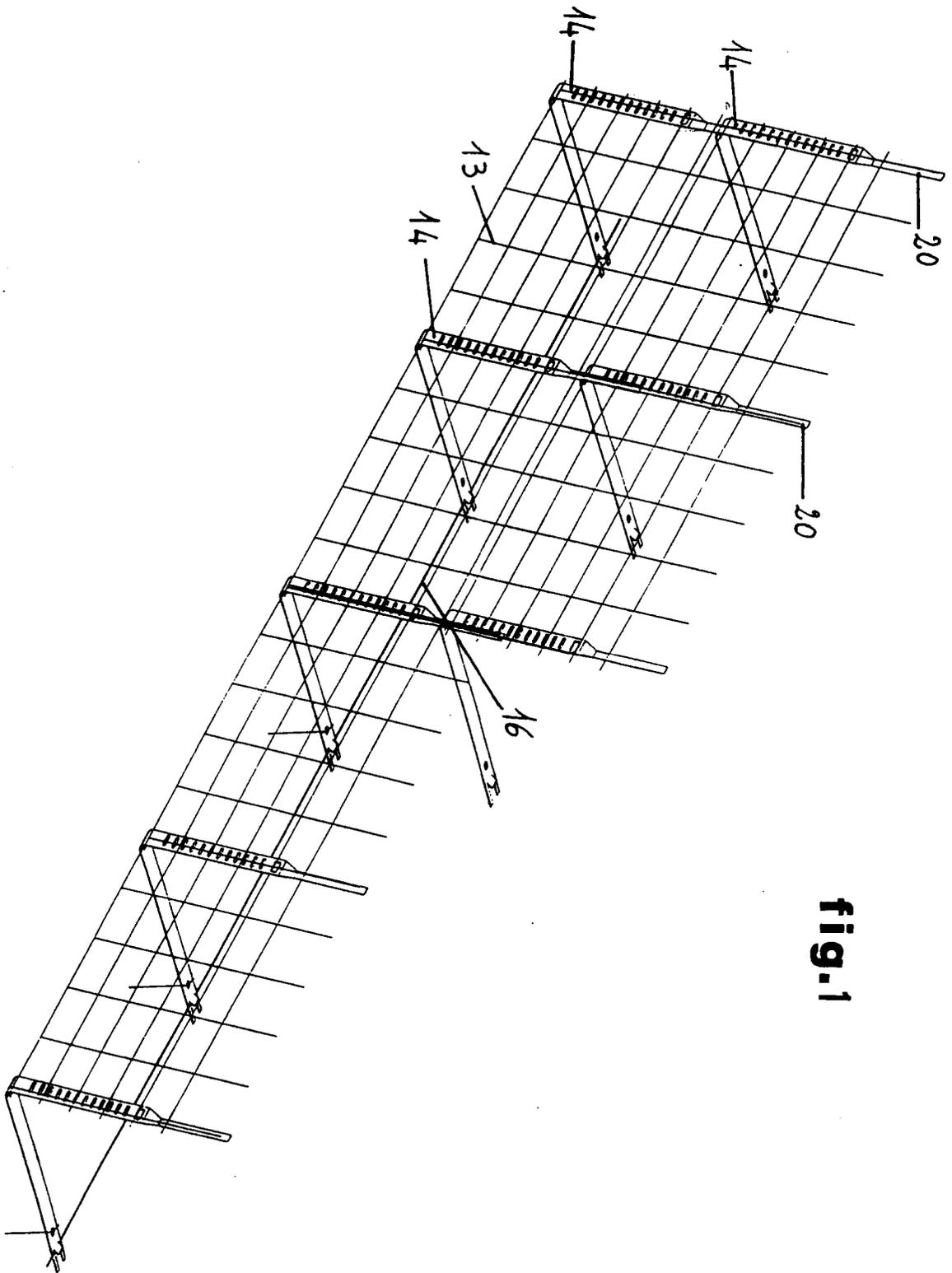


fig.1

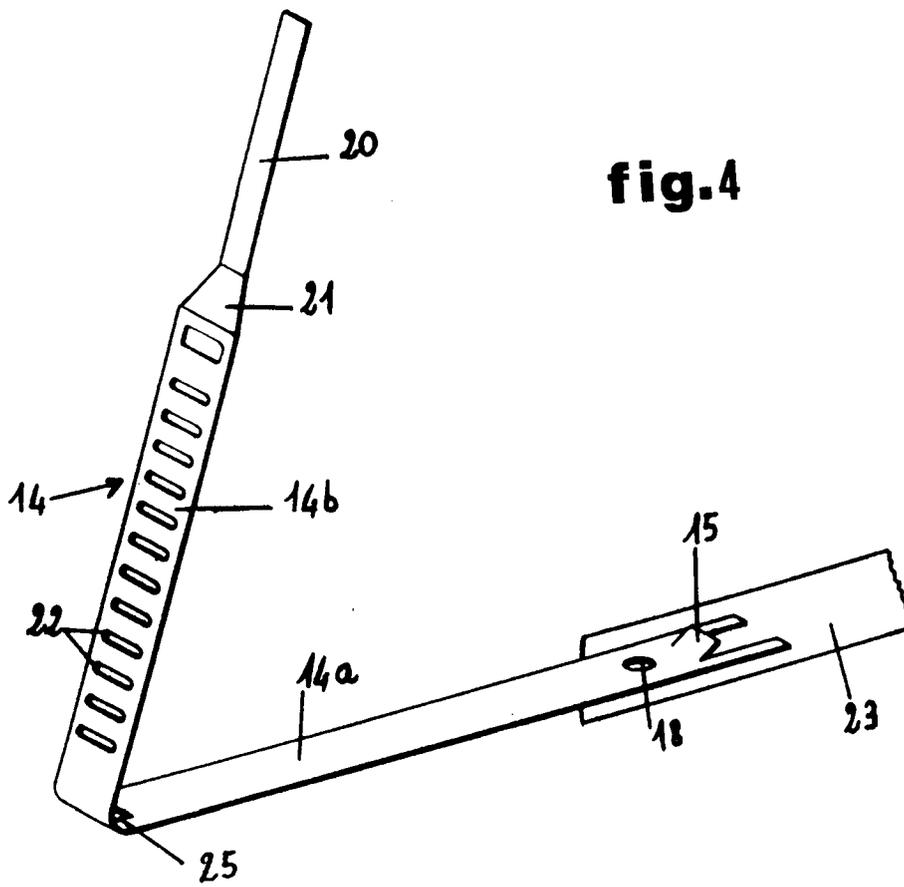
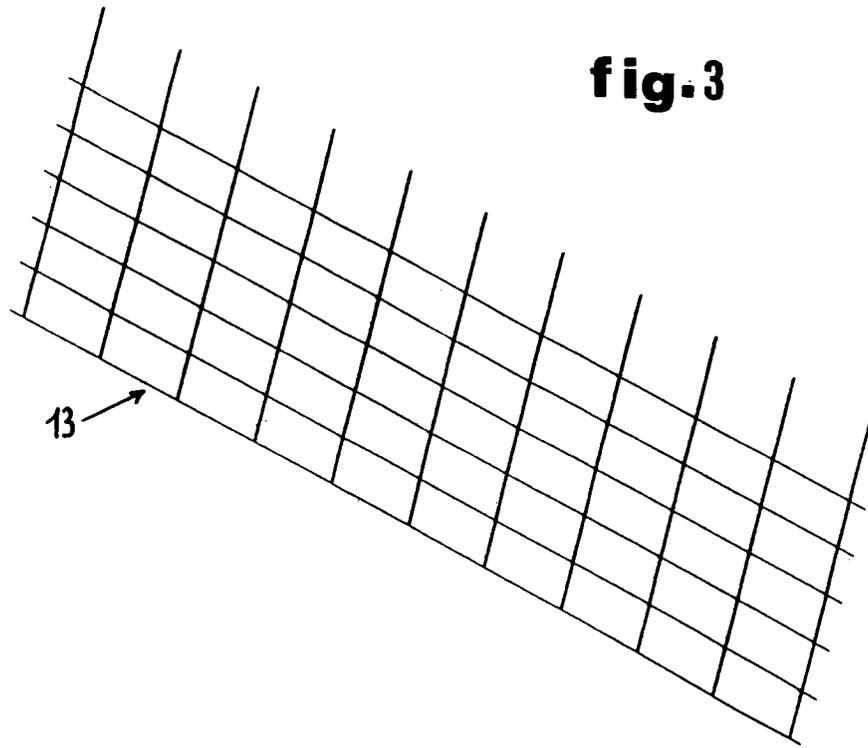


fig.5

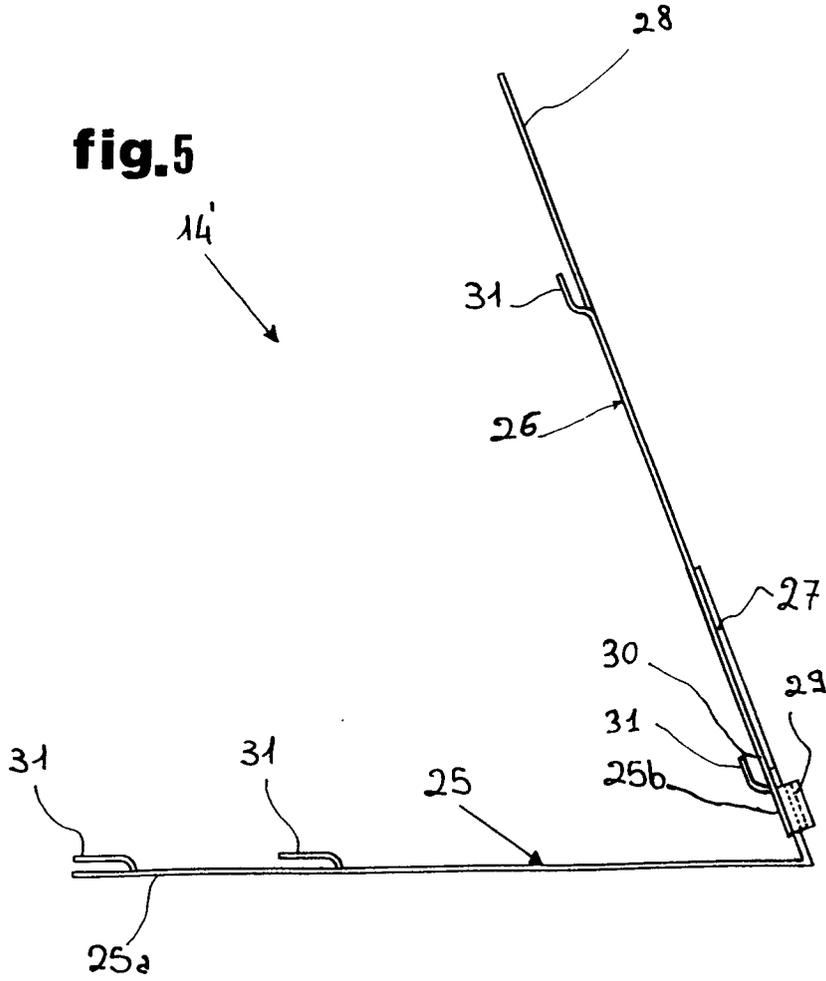


fig.6

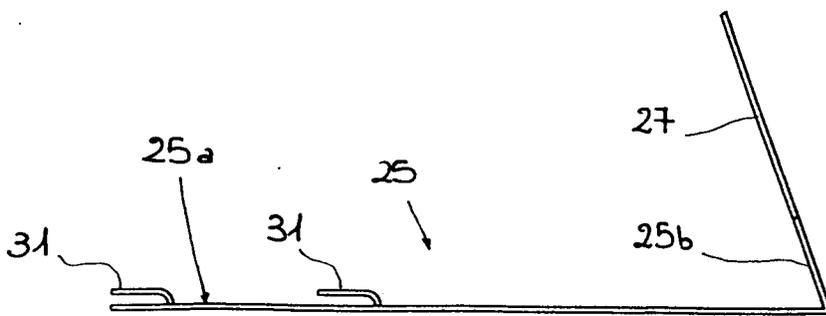
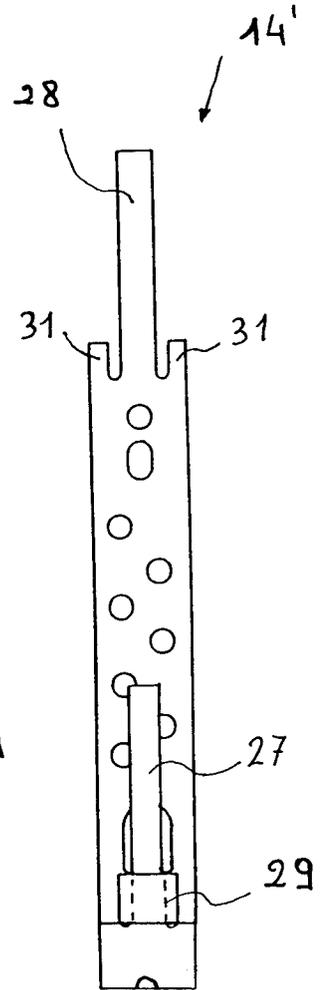


fig.7

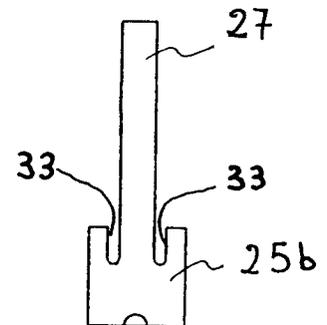


fig.8

fig.9

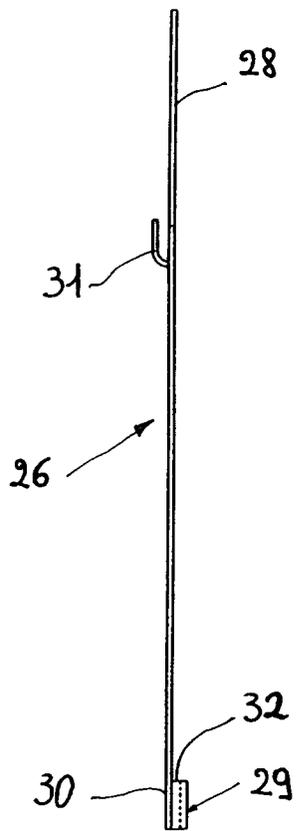
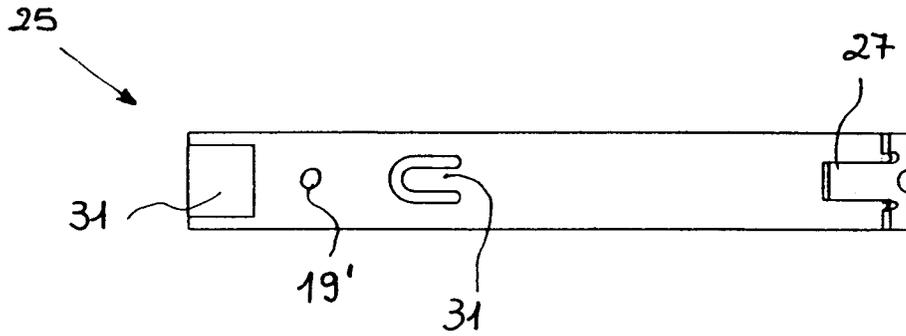


fig.10

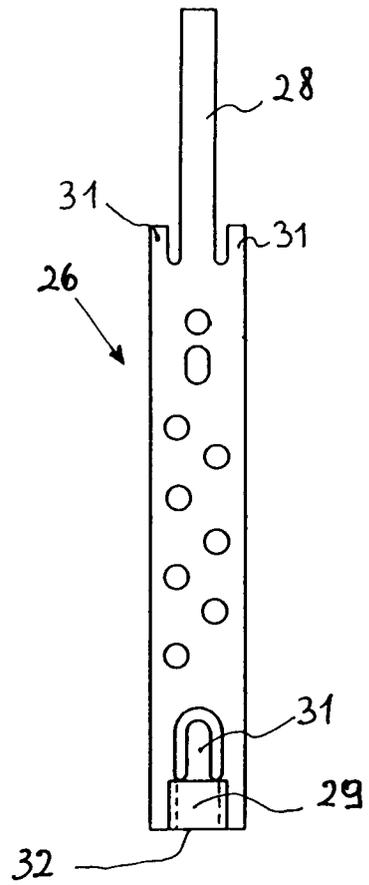


fig.11



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 93 30 4454

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X Y A	DE-U-8 326 632 (WREDE) * page 7, line 4 - page 12, line 9; figures 1-7 *	1,3-5,11 2	E02D29/02
Y A	--- EP-A-0 318 243 (VIDAL) * column 4, line 50 - column 6, line 37; figures 1-8 *	2 10-13	
X,P	--- CH-A-680 078 (BOSSARD & STÄRKLE) * the whole document *	1-13	

			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			E02D
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 31 AUGUST 1993	Examiner TELLEFSEN J.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document	

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