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(54) **Process for the consolidation of excavation faces by means of expansible tension member**

(57) Reinforcing element, called tension member, with variable geometry for the consolidation of soils and excavation faces produced by a mechanical tension member encapsulated in a pipe-shaped sheath which surrounds it adhering to the outer surface of the tension member for its entire length. The tension member is usually constituted by a rod made of fibreglass or another composite material having a plurality of longitudinal grooves intended to house a portion of sheath and has a central duct for conveying injected grout, while the covering is constituted by a sheath made of robust fabric. The installation procedure entails making the borehole in the ground, inserting the reinforcing element and pressurised injection of grout through the feed duct into the space between sheath and tension member causing radial dilation of the sheath until it is pressed against the inner wall of the borehole. The shape of the section of the sheath and/or the elasticity thereof allow the sheath to dilate radially retaining the grout and to exert a desired hydrostatic pressure against the soil. Control of the pressure of the grout inside the sheath allows control and uniform distribution of the tangential friction forces along the entire length of the tension member both between soil and grout and between grout and tension member.

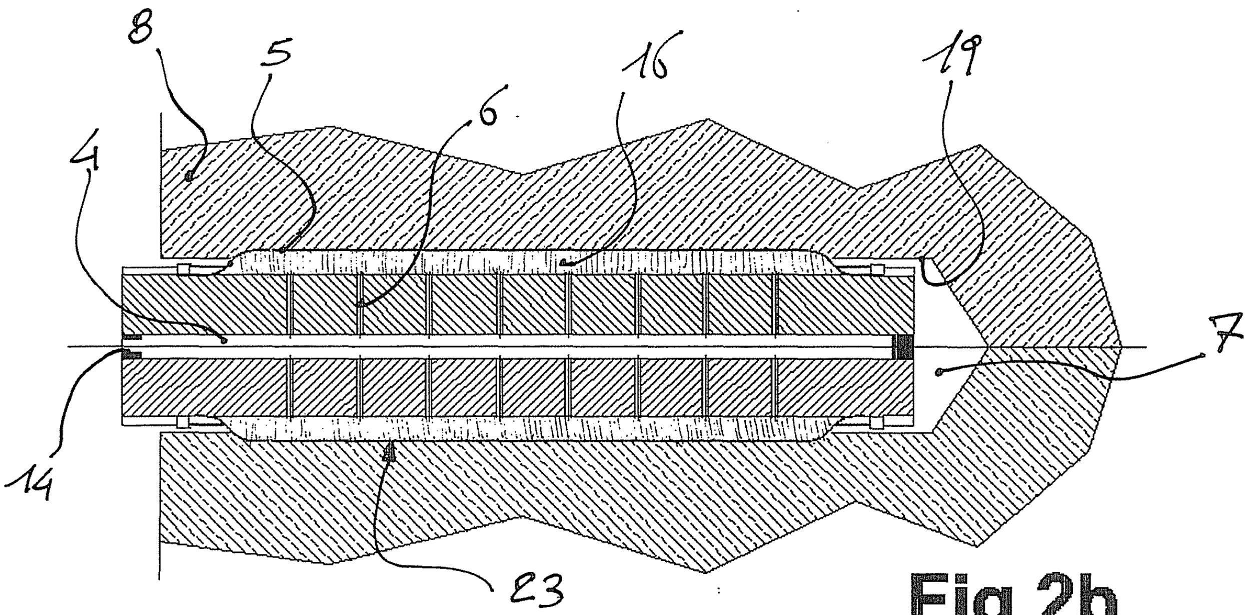

Fig 2b

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Description

[0001] The present invention relates, in general to the building sector, more specifically to the procedure for installation of an innovative tension member for the consolidation of excavation faces.

[0002] Over the years the excavation of tunnels has undergone considerable evolutions, mainly made possible by the use of modern equipment and new materials which as a whole have actually allowed to perform large civil engineering works which were impossible in the past. An area where research efforts have been concentrated is undoubtedly the field of excavation in soils with low cohesion subject to the danger of landslips both during and after execution of the works, in order to make excavation safe and quick.

[0003] In large civil engineering works which require the excavation of tunnels or large-scale earth movement, it has become common practice to consolidate the excavation face to prevent landslip, especially in the presence of clayey formations which make the stability of the excavation face precarious, as removal of soil locally introduces drastic reduction in the capacity of the soil to withstand the increased stresses caused by the excavation works.

[0004] It is worth to mention that until a few years ago, the problem of stability of the excavation face inside a tunnel was tackled solely to guarantee a temporary retaining action inside the cavity and on the face itself, in order to decrease excavation difficulties and relinquishing, after excavation, the opportunity of co-operating in the statics of the work in the short and long term. For this purpose operational works performed were typically limited to a small peripheral area of the excavation face.

[0005] With the coming of new high strength synthetic materials, which were easy to demolish during excavation operations, it became possible to tackle the problem of stability in a broader dimension, extending the consolidation action beyond the physical dimensions of the excavation and consequently permanent and effective in the long term.

[0006] The procedure brought about a revolution in the sector as it allows the soil mass in front and upstream of the excavation face to acquire the necessary mechanical properties to support the increased stresses caused by excavation, making operations for mechanical retention downstream of the tunnel unnecessary and also allowing co-operation in the static resistance of the civil engineering work for its entire life.

[0007] Consolidation typically takes place by inserting a series of reinforcing elements arranged strategically on the excavation face along an area peripheral to the path of the tunnel. Each reinforcing element is substantially constituted by a deep borehole of suitable diameter and of a pre-selected length inside which "tension members", typically constituted by reinforcing rods, are inserted at the centre of the borehole; the hole is then filled with special grouts injected under high pressure. By combining the high reinforcing capacities of fibreglass reinforcements with the possibility of performing high pressure injections, surprising reinforcing actions extended to wide areas peripheral to the tunnel are obtainable.

[0008] Insertion of these reinforcements upstream of the excavation face makes modification of the tensile state of the soil less traumatic, compensating weakening caused by excavation thanks to the mechanical action of traction of the tension members which exert an effective retaining action on the soil, thanks to fibreglass rod-cementation-soil adherence which is substantially exerted through the exchange of tangential forces parallel to the longitudinal direction of the glass fibres which react by offering high tensile strengths.

[0009] Excavations can thus be carried out in "consolidated" soil enabled to absorb stresses caused by aperture of the cavity without the need for particular expedients for partial removal of the reinforcements, which are destroyed by usual mechanical excavation means only in the excavation area, remaining instead in place for the entire remaining length.

[0010] Thus the consolidated soil remains capable of actively co-operating in the statics of the cavity, thereby reducing the load part and allowing performing excavation works with increased speed and safety.

[0011] It is thereby understood how the consolidation of excavation faces represents a phase of crucial importance in modern excavation processes, moreover representing a significant portion of the cost.

[0012] Not by chance, modern building technology has rapidly evolved with respect to consolidation materials and technologies and is still active in the search for materials which are increasingly strong, practical to install, safer and also increasingly easy to demolish and recycle to minimise atmospheric pollution.

[0013] Among the most popular known techniques, the use of fibreglass tension members stands out; these are inserted inside deep holes bored in the ground and then filled with suitable injected grouts. The tension members are usually constituted by one or more fibreglass profiles kept parallel with and strategically distanced one from another so that they can co-operate in tension and simultaneously offer a good grip with the injected grout. One of the most widely used is the star or triangle shape where three bars with a rectangular section are arranged to form an equilateral triangle or a three-sided star, or the more common tubular section.

[0014] It is important to point out that the soil is able to cling to the fibreglass or composite material tension member to the extent that, by friction, the soil is able to transmit shearing forces to the grout which, in turn, transmits it to the fibreglass profiles and therefore said profiles can in fact exert an effective retaining force to the extent that, with a double passage soil-grout and grout-tension member, a good level of friction is established in both passages.

[0015] It is specified that while on the one hand it is relatively easy to produce reinforcing elements with superb axial tensile strength, it is instead difficult, and often limiting, to ensure good and uniform grip by friction between grout and soil which is often well below the tension limit of the tension member. Notwithstanding the fact that high quality expansive grouts are used, it must be remembered that the soil has uneven compactness and the operation to clog the hole is somewhat problematic. Consequently, the mechanical pressure that the grout exchanges with the soil varies chronically inside the hole and the trend of the friction forces that can be exerted (and therefore grip on the reinforcement) is inconstant, making it necessary to introduce wide and costly safety coefficients in order to compensate the uncertain uniformity of the pressure exerted both between grout and soil and between grout and tension member.

[0016] The problem is not limited only to the soil-grout interface, but also involves the grout-fibreglass interface, as the friction coefficient is low and the shape of the outer surfaces of the profiles is usually smooth since the product is substantially a drawn product and, therefore, the effective retaining capacity of the tension member is critical.

[0017] Undoubtedly, the use of special grouts which expand during setting increasing the pressure force both against the profiles and against the soil improves the results, but the increases are modest, increase the costs of the operation and in any case this does not alleviate the risk of uneven distribution of mechanical pressures, linked to the objective difficulty in performing perfect injection of the grout, which, if a chance to do so occurs, enters pockets or infiltrates natural porosities found in the hole, to the detriment of areas of the reinforcement which do not receive the desired pressure, thereby reducing the pulling force of the reinforcement. Another known improvement is to produce the profiles varying the geometric shape of the surfaces in order to offer improved adhesion, but the drawing procedure is difficult, the increases obtained are also modest and costs increase rather than decrease.

[0018] The main purpose of the present invention is to produce a reinforcing element for consolidation injections capable of producing uniform recompression of the soil surrounding the borehole at the excavation face by means of a single tool, powerful and easy to employ.

[0019] Another aim of the present invention is to produce a reinforcing element for consolidation injections capable of offering a reliably constant and uniform grip on the soil along the entire useful length of the reinforcement.

[0020] Another object of the present invention is to produce a reinforcement which minimises the quantity of grout needed to guarantee certain exchange of a desired force with the soil.

[0021] Yet another aim of the present invention is to produce a reinforcement capable of guaranteeing the preceding results, by using less expensive cement grout.

[0022] The present invention attains these and yet other objects by means of a reinforcing element for soil consolidation, apt to be inserted into holes made in the soil characterised by comprising:

- a reinforcing tension member body substantially cylindrical in shape;
- an expansible sheath of substantially tubular shape placed around at least part of the lateral surface of said tension member body and fixed thereto by its free ends so as to make a seal with said lateral surface;
- a duct for conveying injectable grout between the lateral surface of said tension member body and said sheath,

thus proposing a reinforcing element for soil consolidation reinforcements, which is simple, inexpensive and also easy and extremely quick to install.

[0023] The invention also relates to a process for the consolidation of soils, characterised by comprising the following steps:

- opening, in the soil, a hole of suitable diameter;
- insertion of a reinforcing element as above described into the hole;
- injection of cement grout through the duct of said element, until a desired
- pressure is reached, with expansion of said sheath;

solidification of the injected grout.The present invention will now be better described with the aid of the appended figures, wherein:

- figure 1 schematically shows a sectional view of the reinforcing element according to the present invention.
- Figures 1 a and 1b schematically show a cross-section of the reinforcing element according to the present invention in the idle configuration.
- Figures 2a and 2b schematically show a cross-section of the reinforcing element according to the present invention in the operating configuration.
- Figures 3a and 3b schematically show a sectional view of two different embodiments of the reinforcing element according to the present invention.
- Figures 4a and 4b schematically show a sectional view of two further constructional embodiments of the reinforcing element according to the present invention.
- Figure 5 schematically shows a cross-section of the reinforcing element according to another embodiment of the invention.
- Figures 6a and 6b schematically show a cross and a longitudinal section of the reinforcing element of figure 5, inserted into the soil, shown in its idle configuration.
- Figures 7a and 7b schematically show a cross and a longitudinal section of the reinforcing element according to the invention, shown in its operating con-

figuration.

[0024] According to a particular embodiment, the invention relates to a reinforcing element for the consolidation of soils subject to landslip of the type with a tension member body of suitable section and mechanical performances, intended to be inserted into deep boreholes made in the soil and receive an injection of cement grout with the purpose of filler and capable, when the injected grout sets, of mechanically reinforcing by connecting the soil to the tension member, characterised in that it has:

- a reinforcing tension member body substantially cylindrical in shape, preferably although not necessarily made of fibreglass, of appropriate length and outer diameter, having a plurality of longitudinal cavities made in the outer surface to shape the tension member according to a form of grooved shaft;
- an expansible sheath in the shape of a portion of closed cylindrical pipe, preferably although not necessarily made of a waterproof elastic fabric, of a length slightly smaller than the length of said tension member body, which is inserted over the surface of said tension member forcing the shape to copy preferably the shape of the grooved profile of the tension member body, including the surfaces of the cavity; the sheath has both ends firmly sealed to the outer surface of said tension member body so as to produce an expansible and watertight space, said sheath being capable of varying its geometrical shape, in particular of expanding radially due to the injection of the pressurised hydraulic fluid therewithin, passing from an idle position in which it wraps said tension member and has minimum radial dimensions, to an operating position, in which due to said injection into the space existing between tension member and inner surface of the sheath, the latter expands radially, swelling without breaking until it has larger radial dimensions than the borehole in the soil into which the reinforcing element is inserted;
- a duct of suitable diameter for conveying injectable grout, usually positioned in the centre of said tension member and substantially extending for the entire length of the tension member, with two end openings, of which one is hermetically closed and one is open acting as an inlet for injection of a hydraulic fluid, and at least one outlet placed in an intermediate position to said two end openings, radially connecting said duct with the space existing between the outer surface of the tension member and the inner surface of said sheath wrapping it;

said reinforcing element constituted by said tension member covered by said sheath in the idle position being intended to be inserted inside a deep borehole made into the soil to be consolidated and to receive injection of cement grout injected in liquid state and suitably pressurized inside said duct to cause radial swelling of the sheath until the outer surface adheres against the inner surface of the borehole, and continuing to dilate to locally fit the soil and increase the diameter of the borehole until the hydraulic pressure applied to said fluid is equal to the counter-reaction of the soil which counteracts dilation, thereby allowing uniform hydrostatic pressure to be established, both compressing the sheath against the soil and between grout and tension member along the entire useful length of the reinforcing element, thereby guaranteeing uniform exchange of tangential forces between soil and tension member. It is also possible that the tension body does not present the grooves as above described.

[0025] Figure 1 represents a cross section of the reinforcing element 1, essentially composed of three characteristic elements: a tension body (or tension member) 2, a feed duct 4 and an outer sheath 5, which surrounds the tension member 2.

[0026] The tension member 2 is substantially composed by a bar, typically although not necessarily made of extruded fibreglass, with a plurality of grooves 3 arranged in correspondence of the outer surface of the tension member. The tension member has a duct 4 to feed cement grout in a central position and a plurality of small radial holes 6 which connect the central duct 4 to the space existing between the inner surface of the sheath and the outer surface of the tension member.

[0027] The tension member, made, for example, of pultruded fibreglass or equivalent, can be monolithic or have different sections, i.e. star-shaped, triangular or other shapes.

[0028] The figures 1a and 1b show a cross-section of the reinforcing element 1 preassembled and inserted inside a blind hole 7 bored in the soil 8.

[0029] It can be seen that the sheath 5, usually made of a waterproof and elasticized material, extends longitudinally and at both ends has a sealed area 10 where the inner surface 11 of the sheath 5 adheres hermetically to the outer surface 12 of the tension member 2. The connection 10 withstands pressure and is kept stable by interposing suitable binding agents and/or by the application of outer mechanical clamps and/or by thermoforming, not shown in the figure for simplicity. The duct 4 passes through the tension member for its entire length and typically has a closed end 13, an open feed end 14 and a plurality of intermediate radial holes 6 suitably distanced one from another to connect the duct 4 hydraulically with the space 16 existing between the inner surface 11 of the sheath 11 and the outer surface 12 of the tension member 2.

[0030] Each radial hole 6 may have a check valve, not shown in the figure, whose purpose is to facilitate maintaining the pressure of the grout injected into the sheath 5.

[0031] It is specified that the reinforcing element 1 as a whole, is easy to insert into the hole 7 as the outer dimensions of the tension member 2 are smaller than the inner diameter of the hole 7, notwithstanding the choice of section of the tension member 2.

[0032] Figures 2a and 2b describe the procedure to install the reinforcing element 1 described in Figures 1, 1 a and 1b. In particular, Figure 2b shows how, by feeding the inlet 14 of the duct 4 with suitably pressurized cement grout, the injected grout reaches the radial distribution holes 6 and flows into the space 16 and causes progressive radial swelling of the sheath 5 which continues in its radial travel until it comes into contact with the inner surface 19 of the borehole 7 in the soil 8.

[0033] It is important to observe that the cement grout is injected until the pressure value stabilises at a desired load value and that this pressure is stabilised at the expense of the soil which is compacted and increases in diameter. Deformation of the sheath 5 stops in the balanced condition in which the pressure of the grout equals the counter-pressure of the soil which opposes this deformation, a condition that causes deformation (swelling) of the sheath that is nowhere near the bursting limits. This essential condition is possible due to the fact that in the idle position, the grooves 3 produced longitudinally in the tension member 2 contain a considerable portion of volume of the sheath 5 which, when swollen due to the injected grout, can have a perimeter that is already greater than the inner diameter 7 even before it starts to dilate. Progressive injection of grout, destined to be contained volumetrically inside the sheath 5, causes local elasto-plastic deformation of the soil which is actually compressed to enlarge the borehole and creates a counter-pressure reaction that increases with the induced compaction.

[0034] When the injected grout causes swelling of the sheath 5, which changes from the idle position 22 in Figure 1 b (surrounding the tension member 2) to the operating position 23 in Figure 2b (swollen to a desired pressure), due to hydrostatic pressure, both the relative inner/outer surfaces of the soil 8 and the tension member 2, for the portion between the ends 10, namely useful length, are subjected to constant and perfectly uniform pressure. It must be specified that the sheath stops swelling when the soil, which expands due to the pressure, starts to oppose deformation, establishing a counter-pressure which then remains effective when the grout sets.

[0035] This results into an considerable advantage since, not only thanks to an accurate pressure control, high friction forces both between soil and hardened grout and between hardened grout and tension member (and then between soil and tension member) are established, but these forces are also uniformly present along the entire useful length of the reinforcement.

[0036] It must also be pointed out that these friction forces can locally increase by adopting corrugated outer surfaces of the sheath and of the tension member (with improved adhesion) and the effectiveness of this improvement is relevant only to the extent to which the radial pressure force can be increased. This improvement would have little effect in conventional cases but becomes effective in the reinforcing element forming the object of the description.

[0037] In short, the presence of the sheath, whether it is able to expand thanks to its own elasticity, or it is able to expand due to the fact that it is strategically positioned inside the grooves of the tension member, allows a hydrostatic loading pressure to be established before the grout sets, guaranteeing not only friction forces which are locally by far higher, but also perfectly distributed along the entire useful length of the tension member, thereby guaranteeing much greater efficiency than those obtainable by conventional methods which, although utilizing tension members with high tensile strength, actually retain the soil with great disadvantages due to the difficulty in performing uniform injections.

[0038] Figure 4a shows an embodiment whereby the sheath 5 has a circular section while the body of the tension member 2 still has a plurality of grooves 3, while in Figure 4b both the outer sheath and the body of the tension member have a circular shape; in both cases the sheath 5 expands since it is made of a sufficiently elastic material.

[0039] From the above it can be seen how the reinforcing element according to the present invention achieves the proposed results, in particular allowing the following advantages to be obtained:

- the quantity of cement mortar injected is limited by the volume of the dilated sheath and therefore controllable;
- by injection of cement grout, the sheath expands outwards exerting hydrostatic pressure which subsequent to setting results into maximum and uniform static co-operation between soil and reinforcing element, thereby considerably improving the effectiveness of each reinforcing operation;
- due to the combined effect of the push of hydraulic pressure and a noteworthy surface roughness, the outer surface of the sheath can actually exchange higher tangential forces with the soil;
- the reinforcing element is well suited to be utilized with conventional and ordinary cement grouts;
- the reinforcing element, containing, on the other hand, limited volumes of grout, is easy to demolish during excavation operations and subsequently easy to dispose of as refuse.

[0040] According to a further embodiment, the invention relates to a reinforcing element for the consolidation of soils subject to landslip of the type with a tension member body of suitable section and mechanical performances, intended to be inserted into deep boreholes made in the soil and receive an injection of cement grout with the purpose of filler and co-operating with an outer sheath capable of expanding due to cement grout injected inside swelling until the grout establishes with the soil a desired pressure, characterised in that:

- said tension member body is composed of a thin walled hollow pipe with substantially cylindrical shape and internal cavity, preferably although not necessarily made of composite material, with appropriate length, thickness and outer diameter, having along a major part of its length a longitudinal cut substantially parallel to a generatrix of its outer surface, conferring to the pipe's cross section a "C" shape;

- said pipe having a closure plug positioned at each end, whereof the external end plug, named feed plug, has a hole of suitable dimensions for introducing grout under pressure into the cavity of said pipe, the opposite plug having closure function;
- said expansible sheath in the shape of a closed tubular sheathing portion, preferably although not necessarily made of a waterproof non-elastic fabric, of a length slightly smaller than the length of said tension member body and definitely larger diameter, wherein said tension member is inserted, the sheath adhering to the outer surface of said pipe, the exceeding portion of sheath being gathered in correspondence of said longitudinal cut provided in said tension member body;
- at least a clamp is provided in correspondence of each end of said pipe , fixing said sheath to said pipe by radially tightening the sheath, establishing a mechanical and hydraulic seal;
- said exceeding portion of sheath being introduced and stored inside the cavity of said tension member body through said cut along the whole available length defined between the clamps;

said reinforcing element constituted by said longitudinally cut pipe covered by said sheath in a idle position being intended to be inserted into a deep borehole made into the soil to be consolidated, the injection of cement grout in liquid state and under suitable pressure into said cavity of said pipe through said feed plug causing radial swelling of the pipe that, unable to withstand the pressure opens by considerably widening the longitudinal cut, expelling the portion of sheath originally stored inside, causing radial swelling of the sheath until its outer surface adheres against the inner surface of the borehole, and continuing to dilate to locally fit the soil and increasing the diameter of the borehole until the hydraulic pressure applied to said fluid is equal to the counter-reaction of the soil which counteracts dilation, thereby allowing uniform hydrostatic pressure to be established, both compressing the sheath against the soil and the grout against the tension member along the entire useful length of the reinforcing element, thereby guaranteeing, through the grout, uniform exchange of tangential forces between soil and tension member, at the same time containing the volume of grout required to the operation of the reinforcing element.

[0041] Figure 5 shows a cross section of the reinforcing element according to another embodiment of the invention, comprising a tension member body 101, composed of a thin walled pipe and an outer sheath 102, wrapping tension member body 101.

[0042] Tension member body 101 is substantially composed of a circular cross-section pipe having a longitudinal cut 103 (also named slot) along its entire useful length, which imparts it an open "C" shaped structure. Preferably, the cut does not concern the whole length , in particular not the ends, where the ends of the sheath generate a seal with the tension member body.

[0043] The cut 103 has primary functions, by not substantially affecting the tensile strength of the body, while deliberately and considerably reducing its resistance to internal hydraulic pressure besides acting geometrically, as better explained below, as a slot for receiving and housing a portion of sheath inside the pipe.

[0044] The pipe may have an outer diameter of between 40 and 60 mm, while the sheath, if made of non-elastic material, has an outer diameter of between 130 and 180 mm.

[0045] The sheath 102 is generally made of non-elastic waterproof material and is in part inserted into the cylindrical cavity 104 of pipe 101. In particular, it shows a first zone I, made to adhere to pipe 101 on its whole outer surface, with the exception of the zone 103 wherein it is cut, a second zone II, shown with dashed line, representing the portion of sheath exceeding with respect of the pipe 1 diameter, and a zone III, showing how zone II is originally collected inside cavity 104, by forcing zone II through the slot 103 of pipe 1.

[0046] As better shown in the next figure, the sheath presents both its ends tightly sealed on the outer surface of said tension member body, thus forming an expansible and water-tight interspace.

[0047] Figures 6a and 6b show a cross section of the reinforcing element 101 preassembled an inserted inside a blind hole 105, opened into the soil 106. It must be pointed out how the sheath 102 , commonly made of a waterproof and/or elastic fabric, extends longitudinally and has, in correspondence of both ends a zone sealed by means of clamps 107 and 108, which can also be replaced with suitable means, e.g. glue. The inner duct 104 of the tension member body 101, extends along the whole length of the tension member and has commonly a closure plug 110, a feed plug 109, allowing injection of cement grout under pressure inside the cavity 104 of pipe 101. Figure 6b moreover shows the portion L of pipe, wherein the portion of sheath III of figure 5 is housed. It must be noted how the reinforcing element keeps its cylindrical shape, thus being easy to insert into the hole 105 opened into the soil. In figures 7a and 7b, the process is described for installing the reinforcing element 101 of figures 6a and 6b. in particular, figure 7b shows how, by feeding with cement grout, under suitable pressure, the cavity 104 of the pipe 101, through the inlet opening 114, the injected grout first completely fills the cavity 104, then the pressure rises and dilates the pipe 101, which widens the slot 113, in particular along length L of figure 6b, thus expelling the portion of sheath III outside the cavity 104, forcing its swelling until the whole air interspace is filled, existing between tension member and hole 105, in the soil 106.

[0048] The swelling of the sheath 11 continues against soil 106, which is locally fitted, and terminates only when the soil opposes a desired counterpressure, corresponding to a safe "grip" of the tension member.

[0049] The dimensions of the sheath 102 are foreseen so that it reaches its operating configuration without limiting its own deformation or opposing counterpressure due to the reaching of its own deformation limits. In other words, it leaves to the soil the opportunity of deforming and generating a counterpressure.

[0050] When the injected grout causes the swelling of the sheath 102, which turns from its idle configuration III of figure 101 (wrapped around the pipe and partly housed inside the cavity 104 of the pipe 101) to the operative configuration III of figure 7b (swollen until the soil offers a desired counterpressure), due to the hydrostatic pressure, both the soil 106 and the tension member 101, for the length between the ends 107 and 108, named useful length, have their outer/inner surfaces subject to a steady and perfectly uniform pressure.

[0051] The sheath 102 is of primary importance to that regard, since it controls the expansion of the grout, on one side, preventing local leakage and, on the other, allowing the soil to be compressed in elasto-plastic condition until it is able to offer a strong counter-reaction.

[0052] This brings about an enormous advantage, since, not only due to an accurate pressure control, high friction forces are generated both between soil and hardened grout, and between hardened grout and tension member (and thus between soil and tension member) and said forces are evenly distributed along the whole useful length of the reinforcing element.

[0053] From what above explained above, one deduces how the reinforcing element according to the present invention achieves the proposed aims, in particular allows to perform the process according to the teachings of the above description, thus bringing about all the advantages discussed and is moreover easy and cheap to produce.

[0054] The tension member body may be of any suitable material, e.g. fibreglass, carbon fibre or a combination thereof, steel, reinforced PVC, and may also comprise a pipe comprising a steel network.

[0055] The sheath may be of substantially non-elastic material and its radial dimensions are larger than those of the tension member body, thus allowing its expansion with generation of an interspace between sheath and tension member body.

[0056] Alternatively, it may be of elastic material, and apt to expand beyond the radial dimensions of the tension member body. It is thus possible, by means of the injection of grout, an expansion of the sheath, enlarging the reinforcing element beyond the dimensions of the hole in the soil, as described above.

[0057] The material constituting the sheath may be of any suitable kind, e.g. comprising a non-woven fabric.

[0058] The sheath may also be made of a multi-layer fabric, at least one layer having high mechanical resistance and a waterproof layer.

[0059] Of course, the solutions presented above are provided purely by way of example and are therefore non-limiting, since all possible modifications according to the knowledge of the skilled in the art can be made, without departing from the protective sphere of the inventive scope defined by the above description and set forth in the appended claims.

Claims

1. Reinforcing element for soil consolidation, apt to be inserted into holes made in the soil **characterised by** comprising:

   a reinforcing tension member body substantially cylindrical in shape;

   an expansible sheath of substantially tubular shape placed around at least part of the lateral surface of said tension member body and fixed thereto by its free ends so as to make a seal with said lateral surface;

   a duct for conveying injectable grout between the lateral surface of said tension member body and said sheath.

2. Reinforcing element according to claim 1, **characterised in that** said duct is provided in said tension member body.

3. Reinforcing element according to claim 2, **characterised in that** said duct consists of a hole passing longitudinally through the entire length of the tension member and closed at one end.

4. Reinforcing element according to any of the preceding claims, **characterised in that** the outer surface of said tension member body has a plurality of longitudinal grooves.

5. Reinforcing element according to any of claims 1 to 3, **characterised in that** said tension member body has a pipe, having a longitudinal cut, adapted to receive a portion of said sheath.

6. Reinforcing element according to any of the preceding claims, **characterised in that** said tension member body is made of fibreglass or carbon fibre, or a combination thereof.

7. Reinforcing element according to any of claims 1 to 5, **characterised in that** said tension member body is made of steel.

8. Reinforcing element according to any of claims 1 to 5, **characterised in that** said tension member body

is made of reinforced PVC.

9. Reinforcing element according to any of the preceding claims, **characterised in that** said tension member body is a pipe comprising a steel network.

10. Reinforcing element according to claim 5, **characterised in that** said tension member body has a plurality of radial holes on its lateral surface, in a location opposite to the longitudinal cut, holes apt to allow the passage of grout.

11. Reinforcing element according to any of the preceding claims, **characterised in that** said sheath is made of substantially non-elastic material and its radial dimensions exceed those of the tension member body, so as to allow formation of an interspace between sheath and tension member body.

12. Reinforcing element according to any of claims 1 to 10, **characterised in that** said sheath is made of elastic material, and capable of expanding beyond the radial dimensions of said tension member body.

13. Reinforcing element according to any of the preceding claims, **characterised in that** said sheath comprises a non-woven fabric.

14. Reinforcing element according to any of the preceding claims, **characterised in that** said sheath is made of multi-layer fabric, whereof at least a layer with high mechanical resistance and a waterproof layer.

15. Reinforcing element according to any of the preceding claims, **characterised in that** said duct is a pipe, optionally made of plastic material, inserted in a central position inside the tension member body.

16. Reinforcing element according to any of the preceding claims, **characterised in that** said duct is a pipe has a plurality of outlets, each equipped with suitable check valves suited to maintain the pressure of the grout injected in the space between said sheath and said tension member for the period of time necessary for the grout to pass from liquid state to solid state.

17. Reinforcing element according to any of the preceding claims, **characterised in that** said tension member body comprises a plurality of individual rods, preferably although not necessarily made of pulltruded fibreglass and/or carbon fibre, connected to one another by suitable connection means and arranged strategically around said duct.

18. Reinforcing element according to any of the preceding claims, **characterised in that** the outer surface of the sheath and/or tension member show surface roughness.

19. Reinforcing element according to any of the preceding claims, **characterised in that** said expansible sheath is covered with a film of material, preferably plastic, in order to protect it during the transport and installation phase.

20. Reinforcing element according to any of the preceding claims, **characterised in that** said expansible sheath is covered with a sheathing of plastic or metallic material, apt to improve adherence between expanded sheath and soil.

21. Process for the consolidation of soils, **characterised by** comprising the following steps:

opening, in the soil, a hole of suitable diameter;
insertion of a reinforcing element according to any of the preceding claims into the hole;
injection of cement grout through the duct of said element, until a desired
pressure is reached, with expansion of said sheath;

solidification of the injected grout.

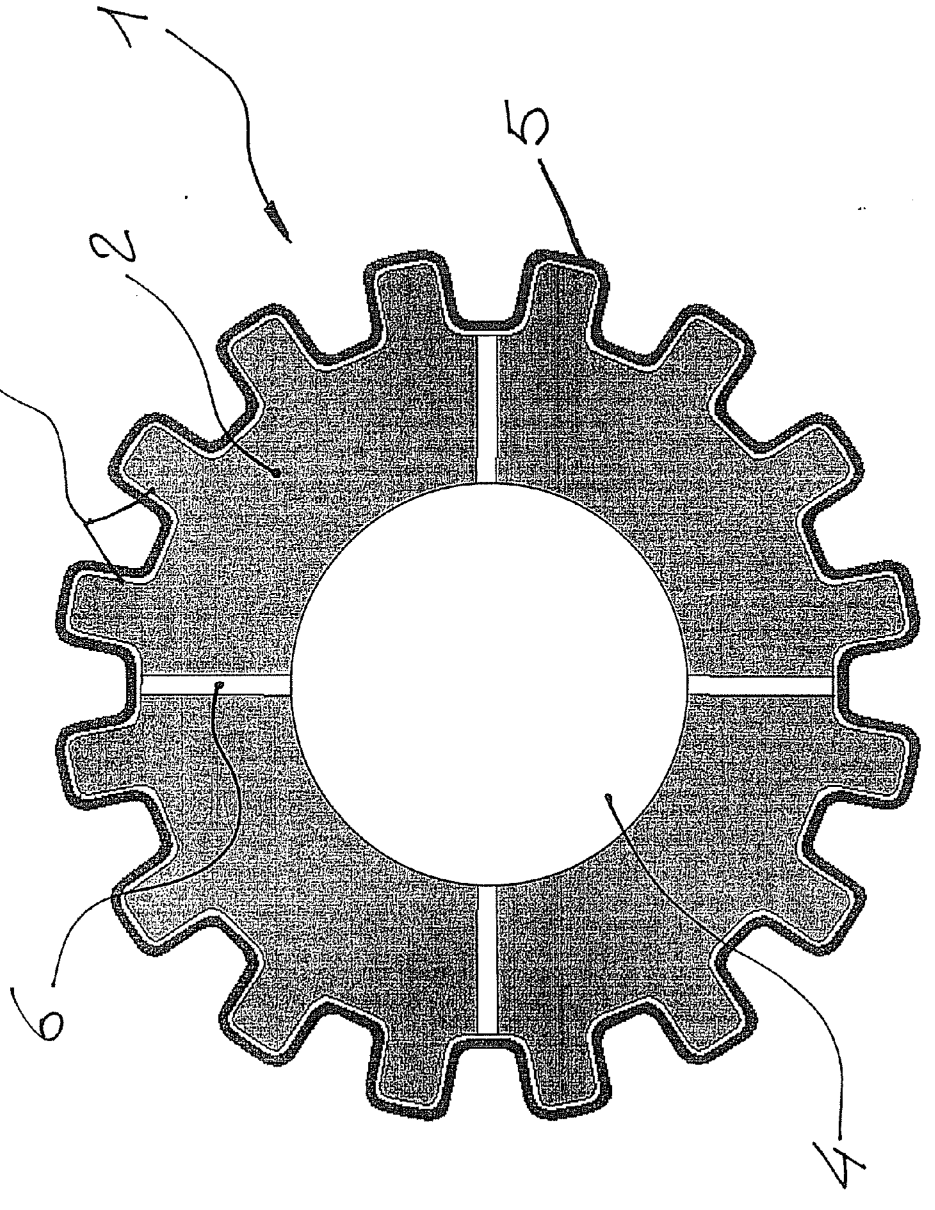

Fig 1

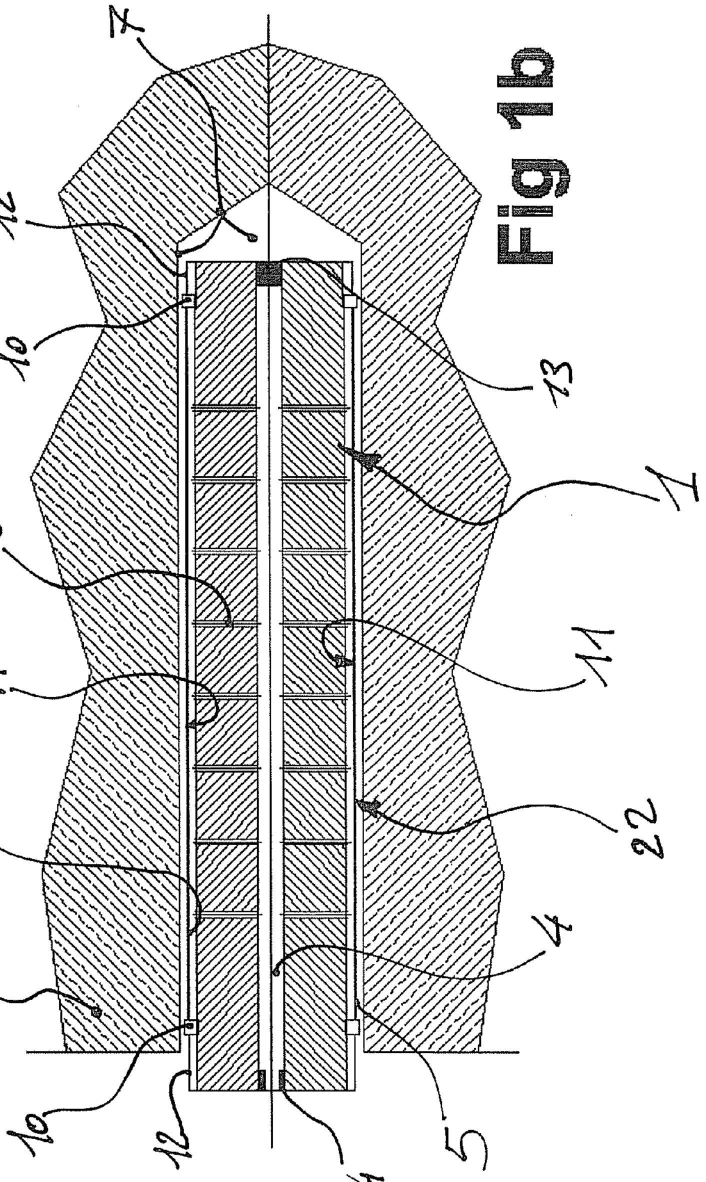

Fig 1b

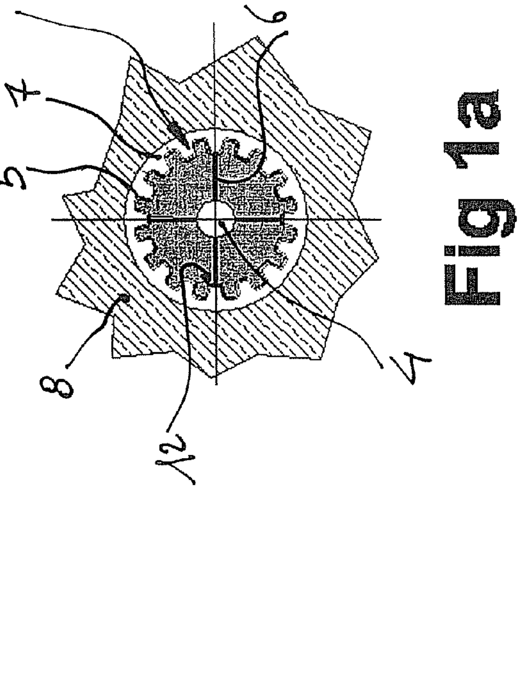

Fig 1a

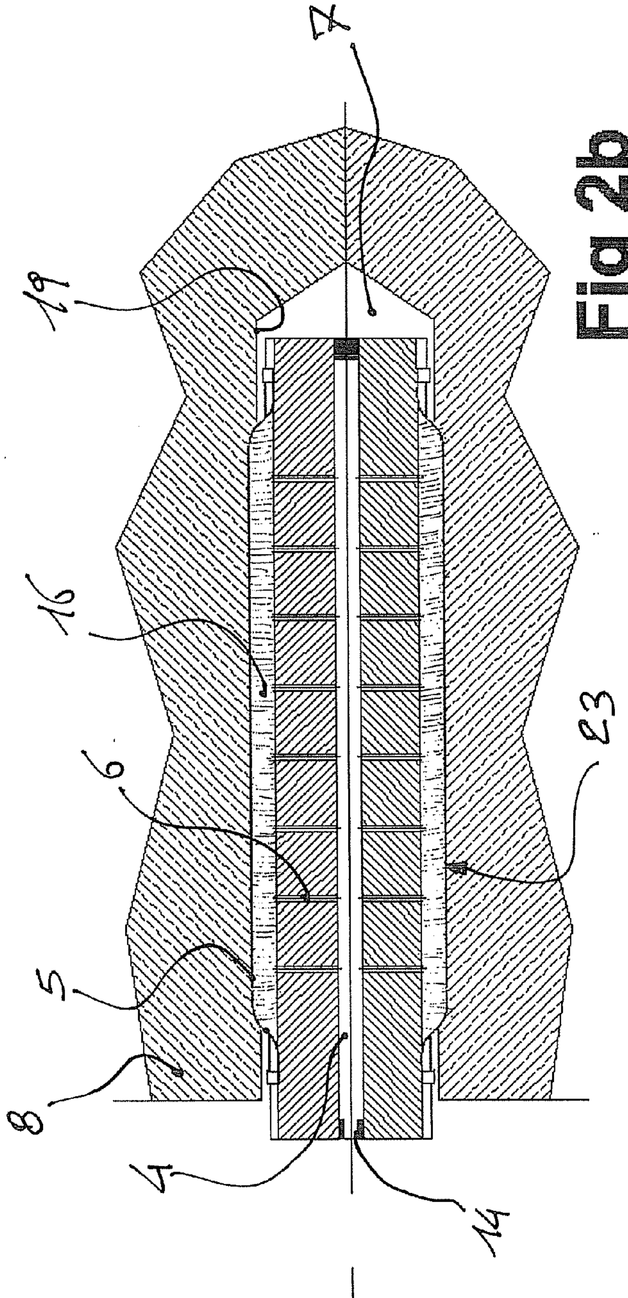

Fig 2b

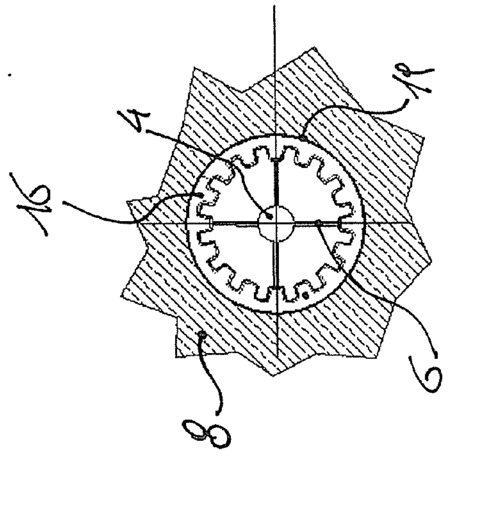

Fig 2a

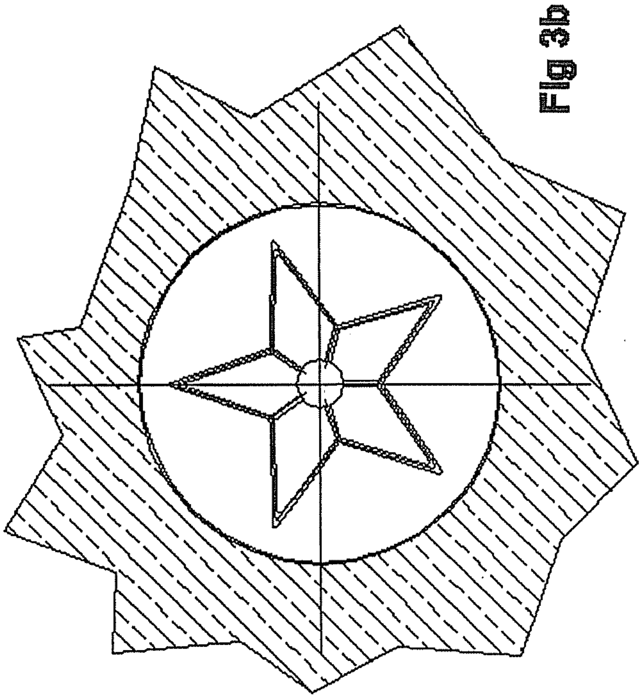

Fig 3b

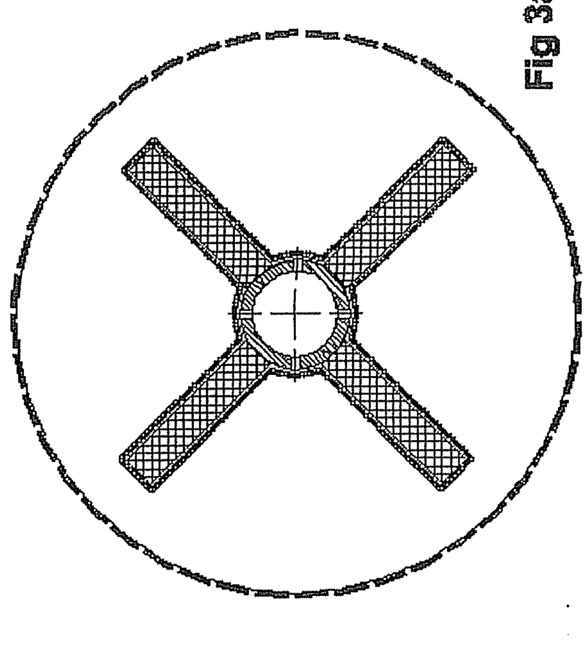

Fig 3a

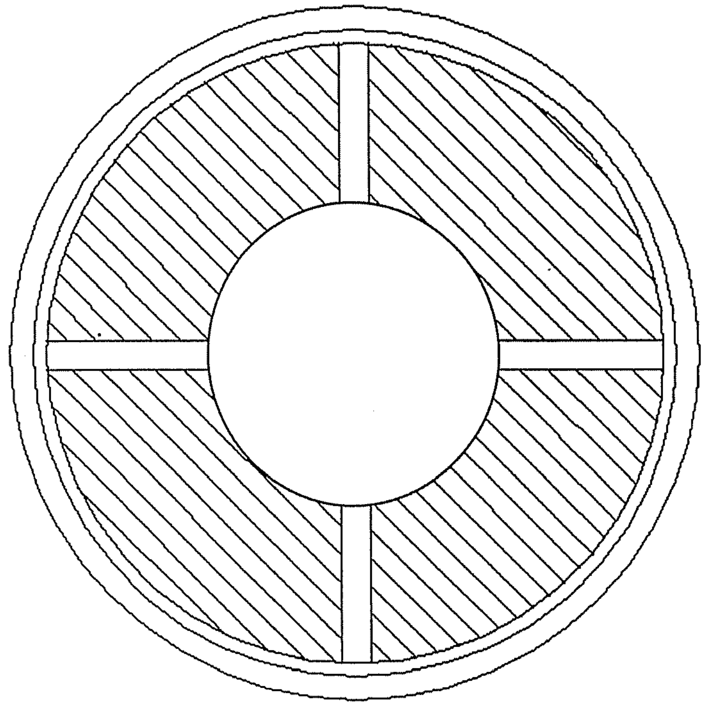

Fig 4b

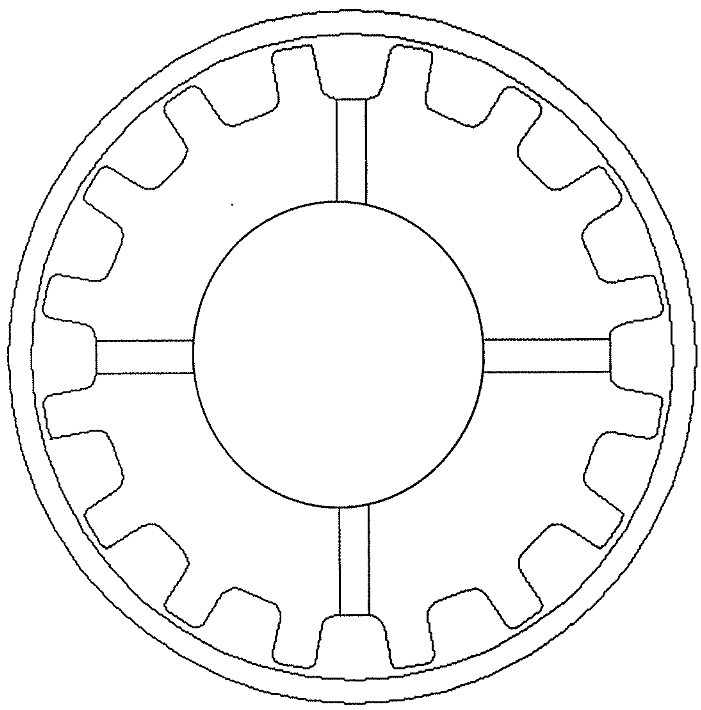

Fig 4a

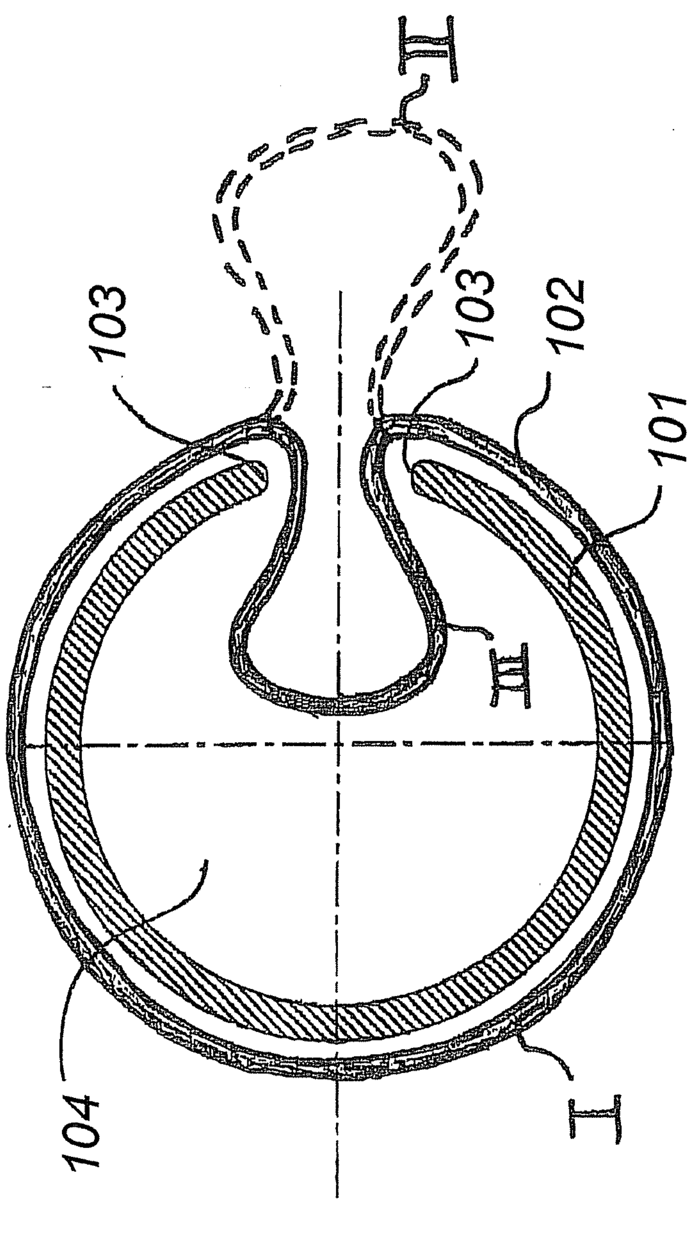

Fig. 5

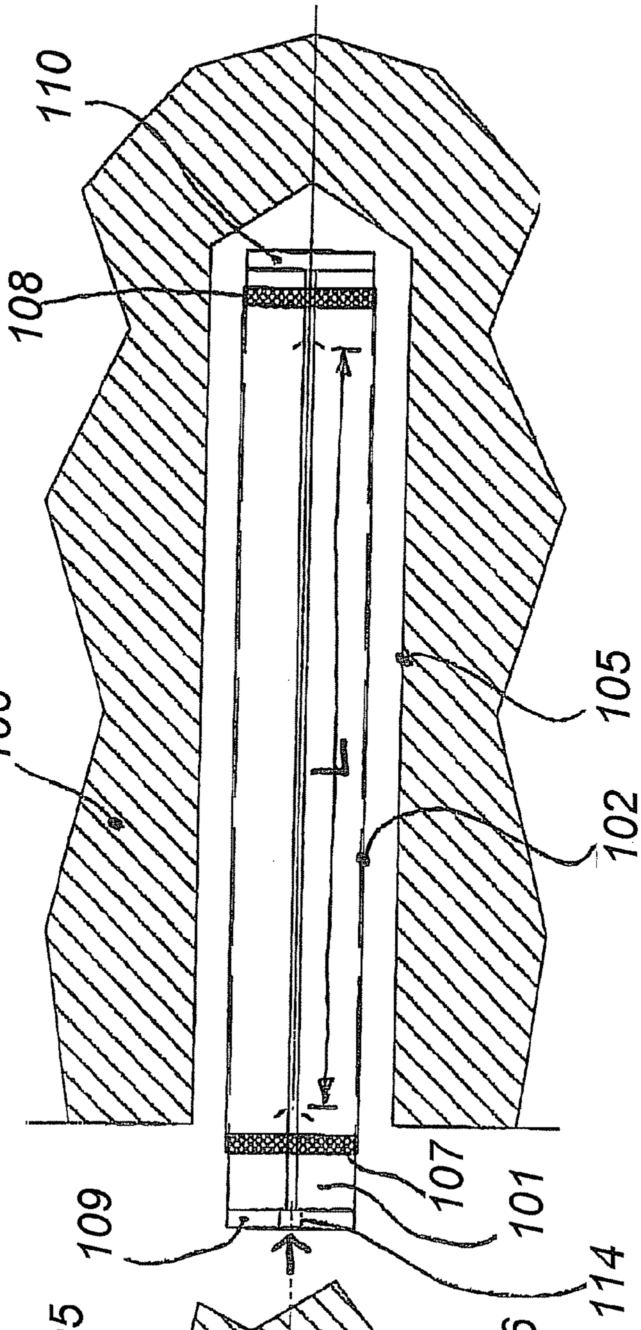

Fig. 6b

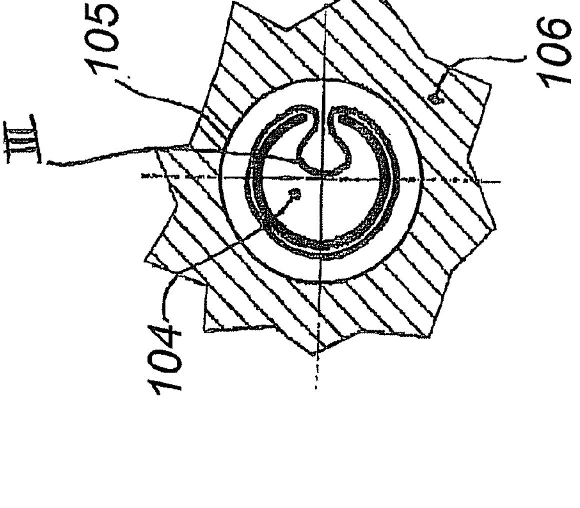

Fig. 6a

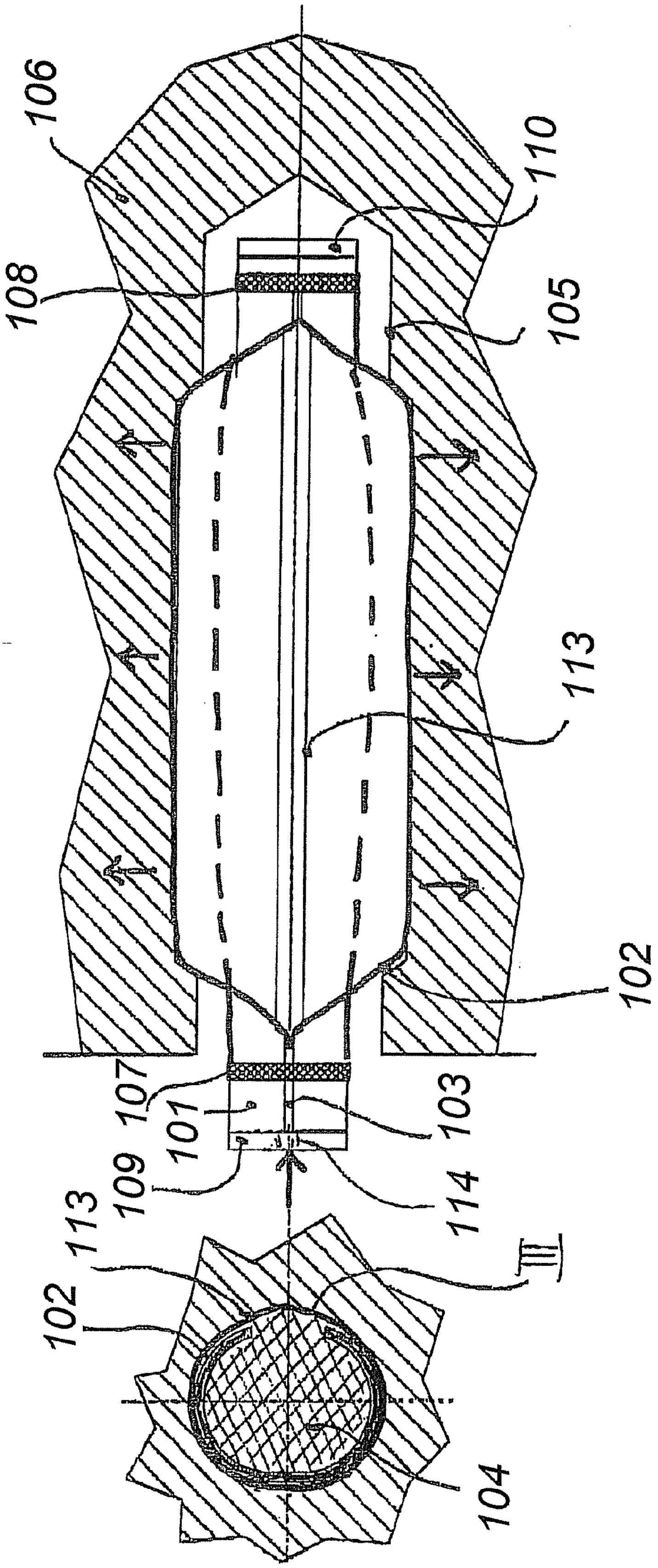

Fig. 7b

Fig. 7a

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 06 10 0622

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 3 496 729 A (FRIEDRICH WILHELM PLEUGER) 24 February 1970 (1970-02-24) * column 2, line 36 - line 67; figures 1,2 *	1-3,6-9, 11-21	INV. E02D3/12
X	DE 34 28 549 A1 (ALTEMOELLER,WOLFGANG K.,DIPL.-ING) 13 February 1986 (1986-02-13) * page 6, line 34 - page 8, line 37; figures 1,2 *	1-3,7,9, 12,21	
X	US 4 832 535 A (CRAMBES ET AL) 23 May 1989 (1989-05-23) * claim 1; figure 1 *	1-3,21	

TECHNICAL FIELDS SEARCHED (IPC)
E02D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	8 September 2006	Str mmen, Henrik

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08-09-2006

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 3496729	A	24-02-1970	NONE		
DE 3428549	A1	13-02-1986	NONE		
US 4832535	A	23-05-1989	DE	3581743 D1	14-03-1991
			EP	0240493 A1	14-10-1987
			WO	8603533 A1	19-06-1986
			KR	9312067 B1	23-12-1993

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82