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(54) **Improved anchoring element for ground consolidation**

(57) The invention is an anchoring element (1; 30) for making ground (S) containment and consolidation structures, comprising: a tubular bar (2) with mainly longitudinal development driven into the ground (S), in which it is constrained by means of a cement mix; one or more cables (5) arranged inside the bar (2) and constrained in the cement mix (C) present inside the bar (2); and a fixing unit (6) suited to fix the anchoring element (1; 30) to the ground (S). The fixing unit (6) is connected to the ends (5a, 2a) of the cables (5) and of the bar (2) projecting from the ground (S). The cement mix (C) fills the bar (2) completely and the cables (5) are buried in the cement mix (C) for their entire length. According to a variant embodiment, the cement mix (C) fills the bar (2) partially, for a section of its length (Cb) in which the ends of the cables (5) are immersed.

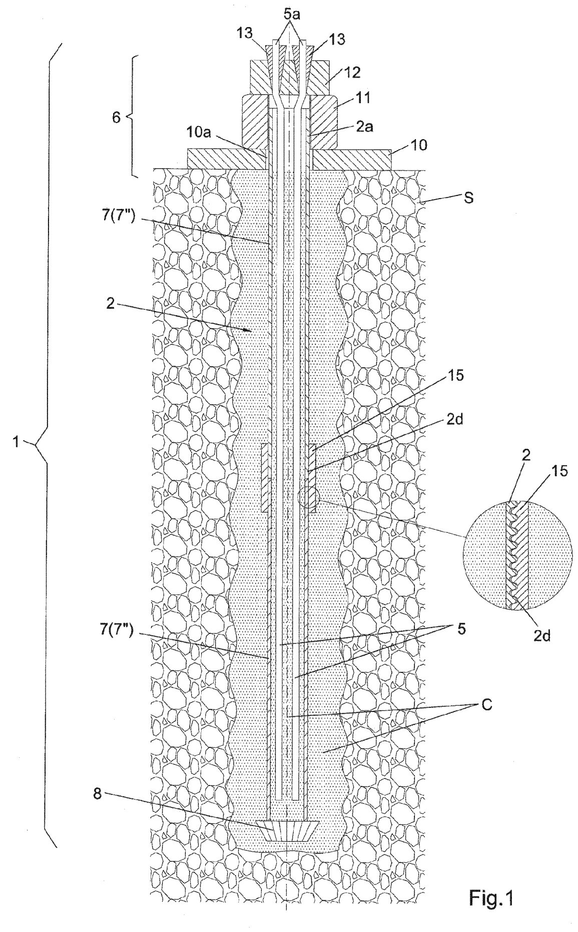

Fig.1

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Description

[0001] The invention concerns an improved anchoring element particularly suitable for making slope consolidation structures, for stabilizing landslips, for making anchoring structures in various geotechnical applications.

[0002] Anchoring elements are known and widely used, which are constituted by tie rods made with prestressed steel strands or by solid bars in structural steel that are constrained in corresponding holes made in the ground through a cement mix.

[0003] Anchoring elements are also known that comprise self-perforating hollow bars generally consisting of a plurality of tubular elements that are threaded externally and axially connected one after the other through joining sleeves as they are driven into the ground.

[0004] The end of the first tubular element is provided with a perforating head and the tubular element is inserted in the ground through a rotary movement or a rotary percussive movement to which it is subjected by special power means.

[0005] While the ground is being perforated, a draining fluid is pumped into the bar, wherein said fluid can be air, water or more commonly a mixture of cement and water, called cement grout.

[0006] Once the desired perforation depth has been reached, a fluid consisting of water and cement is pumped in together with additives, if any, and the hardening of the injected fluid guarantees that the bar is anchored into the ground.

[0007] Anchoring elements of the type described, in particular those using self-perforating bars, are widely and effectively used in many types of application. With regard, in particular, to self-perforating bars, each one of them, when set in operation, is capable of developing a counteracting force that increases as its cross section increases.

[0008] Obviously, even the cost of each bar increases as its cross section increases.

[0009] It is thus absolutely evident that the cost of a containment work depends on the number and size of the anchoring elements that must be installed, which in turn depend on the total thrust they have to be able to oppose once they have been laid.

[0010] In particular, the cost of the work increases with substantially linear proportionality as the cross section and the number of the bars used increase.

[0011] The anchoring element is known which is described in the patent document WO 2005/090690, and which comprises a percussion device that makes a hole in the ground and during perforation introduces in the hole a tubular element that is placed on the bottom thereof, as well as tensioning elements constituted by bars or strands that occupy the entire length of the tubular element and of the hole.

[0012] A consolidation cement mix is introduced in the hole and the tensioning elements are set rotating through the rotation of a flange to which the ends of the tensioning elements projecting from the hole are constrained.

[0013] The limitation of this embodiment lies in that the tubular element does not project from the hole, since it occupies just one section of its length, and thus the flange acts exclusively on the tensioning elements to which it is connected. Consequently, the action of constraint to the ground developed by the anchoring element does not exploit the synergy produced by the resistance offered by the tensioning elements and by the tubular element, as the flange acts only on the latter.

[0014] In other words, the presence of the tubular element does not create a synergy with the tensioning elements to develop the constraining action of the anchoring element.

[0015] The present invention intends to substantially modify the limitations described above.

[0016] It is a first object of the invention to provide an anchoring element that is more resistant than known anchoring elements having the same cross section.

[0017] It is another object of the invention to provide an anchoring element whose cost per ton of anchoring element produced is lower compared to equivalent anchoring elements of the known type.

[0018] It is another object of the invention to provide an anchoring element that is more ductile than the known anchoring elements.

[0019] It is another yet not the least object of the invention to provide an anchoring element whose ductility can be modified upon installation.

[0020] The objects described above are achieved by an anchoring element in accordance with the main claim, to which the reader should refer for the sake of brevity.

[0021] Other details of the invention are described in the dependent claims. Advantageously, the anchoring element of the invention represents the implementation of the well-known anchoring technique with self-perforating bars and it can be installed with no need for the operators to substantially modify the way they work when they install self-perforating bars of the known type.

[0022] Still advantageously, the higher ductility of the anchoring element or, in other words, the larger plastic deformation field allowed by it makes it possible to obtain structures that are safer, especially in case of seismic events.

[0023] To further advantage, said higher ductility or larger plastic deformation field can be modified during installation.

[0024] The objects and advantages described above will be highlighted in greater detail in the description of preferred embodiments of the invention that are supplied as indicative, non-limiting examples with reference to the enclosed drawings, wherein:

- Figure 1 shows the longitudinal cross section of the anchoring element of the invention when installed;
- Figure 2 shows the longitudinal cross section of a variant embodiment of the anchoring element of the invention when installed;

- Figure 3 shows a detail of Figures 1 and 2;
- Figure 4 shows a construction variant of the detail shown in Figure 3;
- Figures from 5 to 13 show different steps of the installation of the anchoring element of the invention;
- Figures from 14 to 17 show the forces acting on the fixing unit of the anchoring element of the invention when the latter is installed;
- Figure 18 shows, in the same load-elongation diagram, the curves regarding a self-perforating bar of the known type and the anchoring element of the invention according to an embodiment of the same;
- Figure 19 shows, in the same load-elongation diagram, the curves regarding a self-perforating bar of the known type and the anchoring element of the invention according to a variant embodiment of the same;
- Figure 20 shows, in the same load-elongation diagram, all the curves shown in Figures 18 and 19.

[0025] The anchoring element of the invention is shown in longitudinal cross section and in the installed configuration in Figure 1, where it is indicated as a whole by **1.**

[0026] According to the invention it comprises:

- a tubular bar **2** with mainly longitudinal development driven in the ground **S** where it is constrained by means of a cement mix **C;**
- one or more cables **5** or prestressed steel strands arranged inside the bar **2** and constrained by means of the cement mix **C** present inside said bar **2;**
- a fixing unit **6** connected to the ends **5a** of the cables **5** and **2a** of the bar **2** projecting from the ground **S** to constrain the anchoring element.

[0027] It should be noted that the word "ground" indicates any means or element into which the bar **2** is driven.

[0028] Furthermore, it should also be noted that the term "prestressed steel" indicates a high resistance steel whose characteristics are described in the European standard EN 10138.

[0029] The tubular bar **2** is provided with an external thread **2b** and this makes it possible to make it in the desired length by connecting, through threaded connection sleeves **15,** several tubular elements **7** that are coaxial with each other and arranged one after the other.

[0030] This constructive solution is adopted especially when the tubular bar **2** is very long, since this would make the bar **2** difficult to install and to transport if it were made in single piece.

[0031] It should also be observed that the tubular bar **2** is of the known self-perforating type and is provided with a drill bit **8** arranged at its end that comes in contact with the ground **S** into which it is driven.

[0032] Regarding the cables **5** in prestressed steel, they are of the known type, too, and are available on the market in various versions with a variable number of strands.

[0033] Furthermore, the tubular bar **2** is made of structural steel, the cables **5** are made of prestressed steel and the cement mix **C** that constrains the tubular bar **2** into the ground **S** and the cables **5** inside the tubular bar **2** is constituted by cement grout which is a mixture of cement and water in variable percentages according to the project.

[0034] It should be noted that the term "structural steel" indicates a steel for building applications that is used for metal structures in the field of civil engineering and has the characteristics described in the European standards EN 10210 and EN 10219.

[0035] In the anchoring element of the invention **1,** made according to the embodiment shown in Figure 1, the cement grout **C** fills the bar **2** completely, so that the cable or cables **5** is/are completely buried in the cement grout **C** and thus once the cement grout has set it/they is/are constrained over its/their entire length.

[0036] The anchoring element of the invention can be made even according to the embodiment indicated by **30** in Figure 2, in which the cement grout **C** fills only the terminal part of the bar **2** and thus once the cement grout has set the cable or the cables **5** are constrained only for the length **Cb** corresponding to the cement grout **C** present in said bar.

[0037] It is important to point out that in the two embodiments **1** and **30** the anchoring elements are equal to each other from a constructive point of view, since they comprise the same bar **2,** the same cables **5** and the same fixing unit **6** and differ from each other only for the different constrainment condition of the cables inside the bar **2** that, as explained above, are completely or partially constrained in the cement grout **C.**

[0038] This differentiation is obtained during the installation of the anchoring element and, as can be better understood from the description of the installation procedure provided here below, it makes it possible to obtain, at the end of the work, different conditions of resistance of the anchoring element of the invention, better than those obtainable with the known self-perforating bars. The fixing unit **6** used can be clearly seen in the detail of Figure 3, where it can be observed that it comprises a load distribution plate **10** provided with a through hole **10a** in which the end **2a** of the self-perforating bar **2** is inserted, and a locking nut **11** that is screwed externally at the end **2a** of the bar **2** projecting from the load distribution plate **10** and tightened against it.

[0039] There is also a cable or strand locking plate **12** positioned against the locking nut **11** and provided with one or more through holes **12a,** in each one of which a cable or strand locking wedge **13** is inserted that locks the end of each strand or cable **5** to the plate **12.**

[0040] It should be noted that the words cable, cable locking plate and cable locking wedge will be used from this point onwards.

[0041] It can be observed in particular that the length **11a** of the locking nut **11** exceeds the length **2b** of the end **2a** of the bar **2** to which it is screwed and which is consequently spaced from the overlying cable locking plate **12,** as can be seen in Figures 1 and 2.

[0042] A variant embodiment of the fixing unit indicated as a whole by **26** is shown in Figure 4 and differs from the embodiment just described and shown in Figure 3 only in that it is provided with a locking nut **21** whose length **21a** is shorter than the length of the end **2a** of the bar **2** to which it is tightened and owing to the presence of a spacer ring **23** interposed between the nut **21** and the cable locking plate **12.**

[0043] It can be observed that the inner diameter of the spacer ring **23** is larger than the external diameter of the bar **2** and thus can be coupled with it with a radial play.

[0044] Furthermore, its length **23a** exceeds the length **2c** of the end **2a** of the bar **2** that projects from the locking nut **21,** which thus remains spaced from the cable locking plate **12,** as shown in Figure 4.

[0045] The two embodiments **6** and **26** of the fixing unit are interchangeable, so that it is possible to obtain the anchoring element of the invention, indicated as a whole by **1** and **30.**

[0046] In practice, the installation of the anchoring element **1** is performed according to the sequence represented in Figures from 5 to 13.

[0047] The operations start, as shown in Figure 5, with the arrangement of the first tubular element **7'** that constitutes the self-perforating bar **2** in the vertical insertion position.

[0048] The drill bit **8** is arranged in contact with the ground **S** and the opposite end of the tubular element **7'** is connected to a mechanical unit, not represented herein, which sets it rotating or performing a rotary percussive movement as indicated by the arrows, in order to drive it in the ground **S** according to the known art.

[0049] During the perforation of the ground, cement grout **C** is injected in the bar **2,** so that, according to the known art, said cement grout favours the penetration of the bar by bringing up to the surface all the material that has been excavated during perforation.

[0050] After the insertion of the first tubular element **7',** as shown in Figure 6, a second tubular element **7"** is coupled at its end through a connection sleeve **15** and then the perforation is started again and continued, as shown in Figure 7, until the bar **2** in the desired length has been completely driven into the ground **S** and completely buried in the cement grout **C** present both inside and outside the bar.

[0051] Before the cement grout **C** starts setting, one or more cables in prestressed steel **5** are buried inside it, as shown in Figure 8, the number and size of said cables depending on the resistance that the anchoring element must guarantee.

[0052] In particular, the cement grout **C** fills the bar **2** completely, in which case the cables **5** are buried therein for their entire length.

[0053] Once the cement grout has set, the cables will be locked in the bar **2** and will be tensioned using the known hydraulic or mechanic tensioning means, as will be explained in greater detail below.

[0054] At the end of the operations the bar **2** will be anchored to the ground with the cables **5** tensioned and buried in the cement grout **C** for their entire length, as shown in Figure 9.

[0055] Alternatively, if once the bar **2** has been driven into the ground some of the cement grout **C** contained therein is extracted, the remaining cement grout fills only the terminal part of the bar **2,** up to the height **Cb** shown in Figure 7a.

[0056] In this case, the cable or cables **5** that are inserted inside it will be immersed only with their terminal part, for the length corresponding to the height **Cb** of the cement grout, as shown in Figure 8a.

[0057] At the end of the operations the bar **2** will be anchored into the ground and the cables **5** will in turn be anchored inside the bar **2** only for their terminal part, as shown in Figure 9a.

[0058] Independently of the final conditions shown in Figure 9 or 9a, the ends **2a** and **5a,** respectively of the bar **2** and of the cables **5,** must be constrained to the ground **S** through one of the anchoring units **6** or **26** previously described. Taking as a reference the bar **2** driven in the ground in the configuration shown in Figure 9a and using the anchoring unit in the embodiment indicated as a whole by **6,** the load distribution plate **10** of the anchoring unit **6** is positioned in contact with the ground **S** and then the locking nut **11** is tightened externally to the end **2a** of the bar **2** in order to force it against the plate **10,** as shown in Figure 10.

[0059] Then the cable locking plate **12** is positioned axially against the locking nut **11,** as shown in Figure 11, taking care to ensure that the ends **5a** of the cables **5** are arranged so that they pass through the holes **12a** present in the plate **12.** The cables **5** are tensioned until reaching the desired tensioning values by means of a hydraulic jack **M** that, as shown in Figure 12, is placed in contact with the cable locking plate **12.**

[0060] The ends **5a** of the cables **5** are then locked in the respective holes **12a** through the cable locking wedges **13** that, having a conical profile that matches the conical profile of the respective holes **12a,** lock the cables **5** through radial compression.

[0061] It is evident, as already explained, that the description provided above can be completely referred also to the use of the fixing unit **26,** in which case the spacer ring **23** is superimposed to the locking nut **21** and the cable locking plate **12** is placed against the spacer ring **23** in the configuration shown in Figure 4.

[0062] At the end of installation the anchoring element **30** shown in Figure 2 will thus be obtained.

[0063] At this point, the space inside the bar **2** where there are the cables **5** is filled with cement grout, not shown in the figures, in order to obtain a single block in which the structural steel of the bar **2** and the prestressed steel of the cables **5** work in synergy.

[0064] Furthermore, the filling with cement grout preserves the metal from corrosion.

[0065] It should be noticed that the term structural steel means a steel of the known type suited to be used for geotechnical applications and having a low carbon percentage, while the term prestressed steel means a highly elastic silicon steel of the known type, used in the field of prefabricated building structures.

[0066] It should also be underlined that both the bar **2** and the cables **5,** instead of being made of steel, can be made with other metallic or non metallic materials. The description provided above can be completely referred to the case where the bar **2** driven in the ground in the configuration of Figure 9 is used, in which case, once the operations have been completed, the anchoring element **1** shown in Figure 1 will be obtained.

[0067] Advantageously, the anchoring element of the invention bears loads that are considerably higher than those born by equivalent anchoring elements of the known type, as could be verified by means of tests that will be illustrated further on in the description.

[0068] For this purpose, it is appropriate to describe the static behaviour of the anchoring element **1** when installed, and in particular of the fixing unit **6** that constrains its end to the ground **S** as shown in Figures from 14 to 16.

[0069] When the locking nut **11** is tightened against the load distribution plate **10,** as shown in Figure 14, this receives the thrusting action **T** from the underlying ground **S** and discharges it onto the nut **11.**

[0070] When the cables **5** are tensioned by the tensioning jack **M** as shown in Figure 15, they are thrust upwards in the direction indicated by the arrow **F** and the reaction of the tensioning jack **M** is discharged onto the nut **11,** generating a compression force **F'** contrary to the tensioning force **F.**

[0071] When, at the end of the tensioning operation, the cables **5** are locked by the cable locking wedges **13** and the tensioning jack **M** is removed, as shown in Figure 16, the cables **5** force downwards the cable locking plate **12** to which they are connected and discharge the compression force **F'** against the nut **11.** Therefore, when the anchoring element **1** is in operation, the nut **11** is loaded on its opposing faces by the forces **T** and **F'** that are contrary to each other, as shown in Figure 16.

[0072] The same considerations apply even if the fixing unit **26** provided with the spacer ring **21** is used, in which case the compression force **F'** will act on the nut **21,** not directly but through the interposition of the spacer ring **21,** as shown in Figure 17.

[0073] The force generated by the cables **5** is discharged onto the load distribution plate **10** and at the end of installation only the load due to the tightening force exerted on the bar **2** will be born by the nut **11** or **21.**

[0074] Advantageously, the anchoring element of the invention described herein, in both its embodiments **1** or **30,** makes it possible to obtain structures that resist to higher loads compared to the structures that would be obtained using self-perforating bars of the known art.

[0075] Laboratory resistance tests have made it possible to verify that the anchoring elements **1** and **30** of the invention guarantee much higher resistance than, for example, self-perforating bars of the known type having the same diameter. Advantageously, this higher resistance involves also a considerable economic advantage.

[0076] In fact, the construction cost of a containment structure using the anchoring elements of the invention and being able to guarantee the same total resistance, expressed in tons, is much lower than the construction cost of structures made with anchoring elements of the known type.

[0077] In other words, the use of the anchoring elements of the invention reduces the cost per constrained ton, as the addition of the metal cables **5** to the self-perforating bar **2** involves a very low percentage cost increase vis-à-vis the percentage increase in the achievable resistance, which instead is very high. Therefore, using the anchoring elements **1** of the invention it is possible to make containment structures that develop greater counteracting forces even though they use a smaller number of anchoring elements compared to analogous structures made with self-perforating bars or other known anchoring elements.

[0078] Even in this case, accounting checks have shown cost reductions that can reach even 60% per ton of counteracting force achievable.

[0079] Furthermore, as already explained, the anchoring element of the invention is more ductile than the known anchoring elements.

[0080] For this purpose, a series of loading tests have been performed on self-perforating bars of the known type and on anchoring elements of the invention in the embodiment indicated as a whole by **1** and also in the embodiment indicated as a whole by **30,** with the cables **5** constrained in the bar **2** respectively for their entire length or partially.

[0081] The diagrams shown in Figures 18 and 19 have thus been obtained, in which:

- the letter **A** identifies the diagram regarding the self-perforating bar of the known type;
- the numbers **1** and **30** identify the diagrams regarding the anchoring elements of the invention in the two variant embodiments, respectively **1** and **30.**

[0082] In the diagrams, the values of the loads are given in the Y-axis and correspond to the pressure, in bars, applied to operate the hydraulic jack that tensions the elements being tested, while the elongation values are given in the X-axis and expressed in millimeters.

[0083] With reference to Figure 18, it can be observed that:

- the values of the ultimate tensile strength **R** of the self-perforating bar **2** of the known type and of the anchoring element of the invention **1** are almost the same and equal to 340 bars;

- in the presence of the same load, the anchoring element **1** of the invention always shows higher elongation values compared to those of the self-perforating bar **A;**
- in the anchoring element **1** the yield effect **Rs** appears in the presence of a load of approximately 200 bars and therefore much earlier compared to the self-perforating bar **A,** where it appears in the presence of a load of approximately 260 bars;
- in the anchoring element **1** the plastic phase **P** extends for a much greater section compared to the self-perforating bar **A** and this makes it more ductile.

[0084] With reference to Figure 19, in addition to the curve relating to the self-perforating bar **A** of the known type, it is possible to observe also three curves relating to three anchoring elements **30** of the invention, each one of which has the cables **5** tensioned with different loads.

[0085] In particular, the curves **30a, 30b** and **30c** are related to increasing tensions on the cables **5.**

[0086] It can be observed that:

[0087] the values of the ultimate tensile strength **R** of the self-perforating bar **A** of the known type and of the anchoring element **30** of the invention are practically the same and equal to 340 bars;

- in the presence of the same load, the anchoring elements **30** always show higher elongation values compared to those of the self-perforating bar **A;**
- in the anchoring elements **30** the yield effect **Rs** appears in the presence of a load of approximately 220 bars and therefore earlier, also in this case, than in the self-perforating bar **A,** where it appears in the presence of a load of approximately 260 bars;
- as the tension of the cables **5** increases, also the stiffness of the anchoring elements **30** increases, which is shown by their lower elongation values in the presence of the same load;
- in any case, the plastic phase **P** of the anchoring elements **30** of the invention extends for a much larger section compared to the self-perforating bar **A.**

[0088] Observing the diagram of Figure 20 that combines the diagrams of Figures 18 and 19, it can be understood that the anchoring elements **1** and **30** of the invention have larger plastic phases **P** than the self-perforating bars **A** of the known type, compared to which, therefore, they are more ductile, thus achieving another object of the invention.

[0089] In fact, the combination of the known cables **5** in prestressed steel with the known self-perforating bars **2** in structural steel makes it possible to obtain a synergy among the different materials used and to obtain a high ductility of the anchoring element, much higher than that obtainable using the known self-perforating bars.

[0090] Said increase in the ductility of the anchoring elements is extremely important when it comes to increasing the safety of the structures, above all those destined to operate in a seismic environment, where it is important to ensure that the structure, even if damaged, will not collapse.

[0091] It can be observed that using the anchoring elements carried out according to the embodiment **30** and properly pre-tensioning the cables **5** means offering the designer the opportunity to modify the ductility of the anchoring element depending on the project, and thus to obtain characteristics that cannot be achieved with the known self-perforating bars, which constitutes a further advantage of the invention.

[0092] It can thus be understood that the anchoring element of the invention, in both its variant embodiments **1** and **30** described herein, achieves all the set objects and advantages.

[0093] It is obvious that the anchoring element can be made using tubular bars in any length and with any diameter, and that any number of cables can be placed inside it according to the loads defined for the project.

[0094] Any variant embodiments, not described herein and not illustrated in the figures, of the anchoring element of the invention, must however be considered protected by the present patent, provided that they fall within the scope of the claims that follow.

Claims

1. Anchoring element (1; 30) for making ground (S) containment and consolidation structures, comprising:

   - a tubular bar (2) with mainly longitudinal development inserted in said ground (S) in which it is constrained through a cement mix (C);
   - one or more cables (5) arranged inside said bar (2) and constrained through the cement mix (C) present inside said bar (2);
   - a fixing unit (6) suited to fix said anchoring element (1; 30) to the ground (S), **characterized in that** said fixing unit (6) is connected to the ends (5a, 2a) of said one or more cables (5) and of said bar (2) projecting from said ground (S).

2. Anchoring element (1) according to claim 1), **characterized in that** said cement mix (C) fills said bar (2) completely and said one or more cables (5) are immersed in said cement mix (C) for their entire length.

3. Anchoring element (30) according to claim 1), **characterized in that** said cement mix (C) partially fills said bar (2) for a section of its length (Cb) in which the ends of said one or more cables (5) are immersed.

4. Anchoring element (1; 30) according to any of the

preceding claims, **characterized in that** said tubular bar (2) is provided with an external thread (2d) and consists of a plurality of tubular elements (7; 7'; 7") that are coaxial with one another and connected one after the other through threaded connection sleeves (15).

5. Anchoring element (1; 30) according to any of the preceding claims, **characterized in that** said tubular bar (2) is of the self-perforating type, being provided with a drill bit (8) arranged at the end that is in contact with the ground (S).

6. Anchoring element (1; 30) according to any of the preceding claims, **characterized in that** said tubular bar (2) is made of structural steel and said one or more cables (5) are made of prestressed steel.

7. Anchoring element (1; 30) according to any of the preceding claims, **characterized in that** said cement mix (C) is cement grout.

8. Anchoring element (1; 30) according to any of the preceding claims, **characterized in that** said fixing unit (6) comprises:

- a load distribution plate (10) placed against the ground (S) and provided with a through hole (10a) in which the end (2a) of said tubular bar (2) is introduced;
- a locking nut (11) tightened externally to said end (2a) and placed against said load distribution plate (10);
- a cable locking plate (12) placed against said locking nut (11) and provided with one or more through holes (12a) in each one of which a cable locking wedge (13) is inserted that houses the end (5a) of a corresponding cable (5) passing therethrough.

9. Anchoring element (1; 30) according to claim 8), **characterized in that** the length (11a) of said locking nut (11) exceeds the length (2b) of the end (2a) of said tubular bar (2) that projects from said load distribution plate (10).

10. Anchoring element (1; 30) according to any of the preceding claims from 1) to 7), **characterized in that** said fixing unit (26) comprises:

- a load distribution plate (10) placed against the ground (S) and provided with a through hole (10a) in which the end (2a) of said tubular bar (2) is introduced;
- a locking nut (21) tightened externally to said end (2a) of said tubular bar (2) and placed against said load distribution plate (10);
- a spacer ring (23) placed against said nut (21);
- a cable locking plate (12) placed against said spacer ring (23) and provided with one or more through holes (12a) in each one of which a cable locking wedge (13) is inserted that houses the end (5a) of a corresponding cable (5) passing therethrough.

11. Anchoring element (1; 30) according to claim 10), **characterized in that** the inner diameter of said spacer ring (23) is longer than the outer diameter of said tubular bar (2) and the length (23a) of said spacer ring exceeds the length (2c) of said end (2a) of said tubular bar (2) projecting from said locking nut (21).

12. Anchoring element (1) according to any of the preceding claims from 8) to 11), **characterized in that** said through holes (12a) of said cable locking plate (12) and said cable locking wedges (13) have conical profiles that match each other.

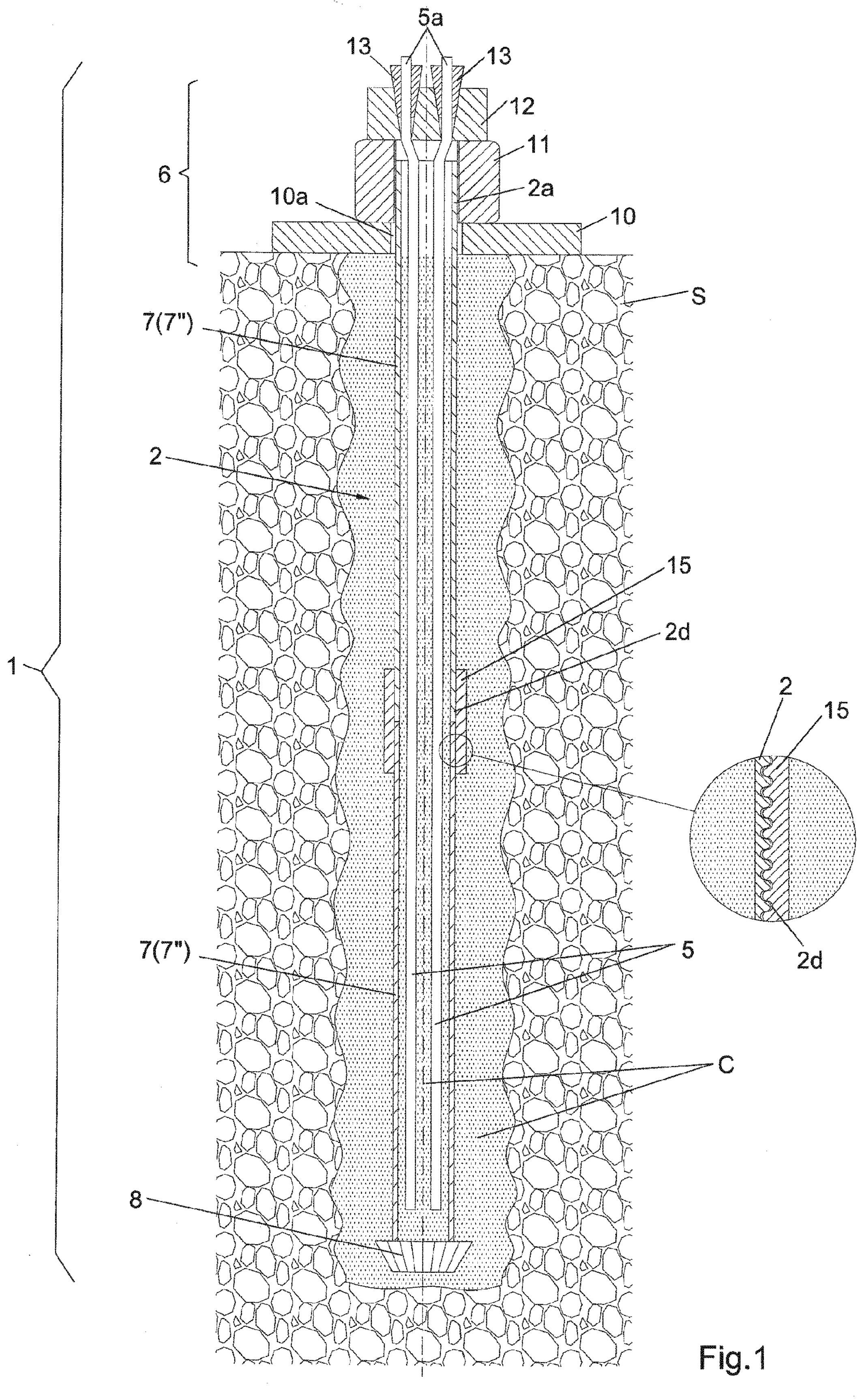


Fig.1

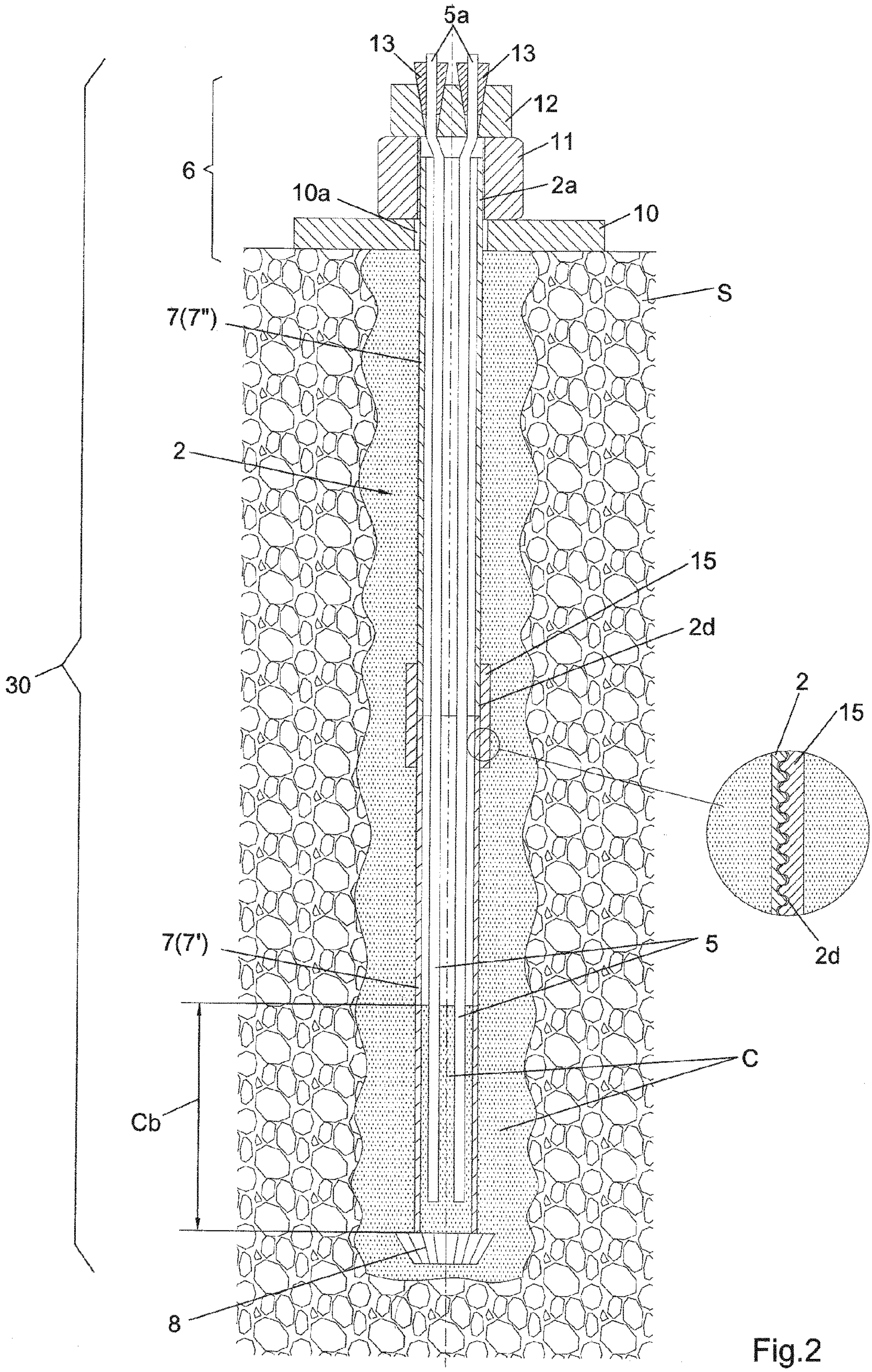


Fig.2

Fig.3

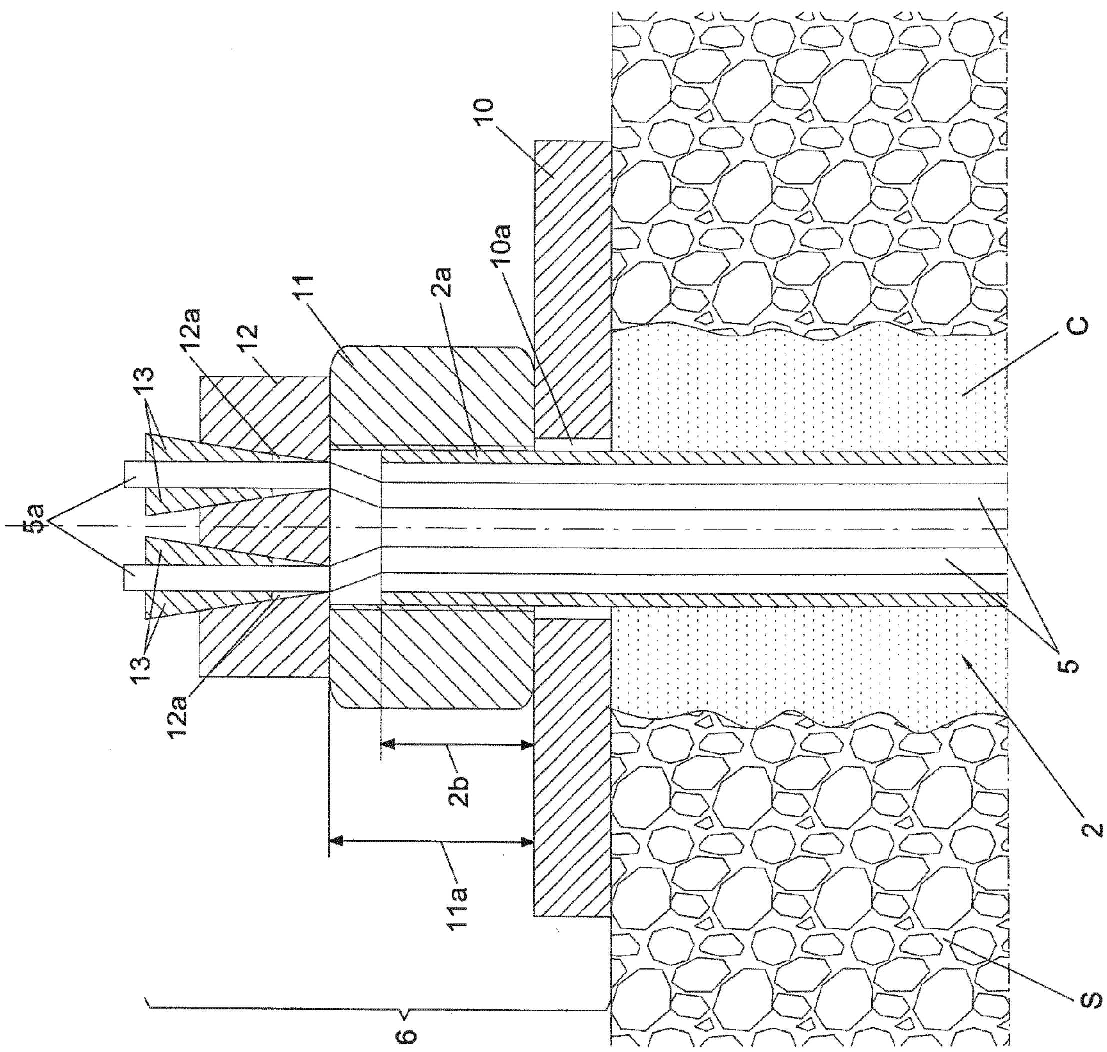
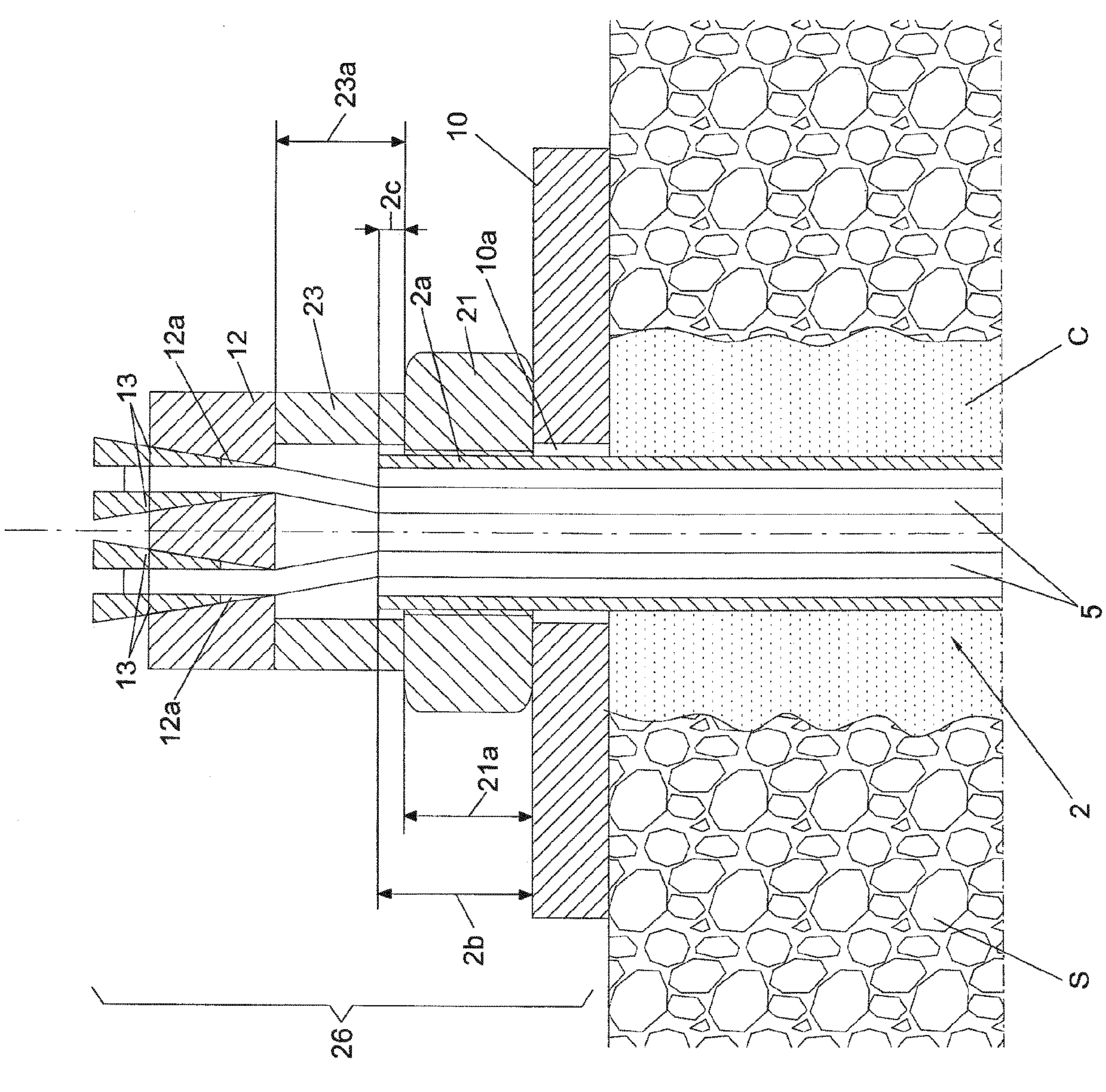


Fig.4



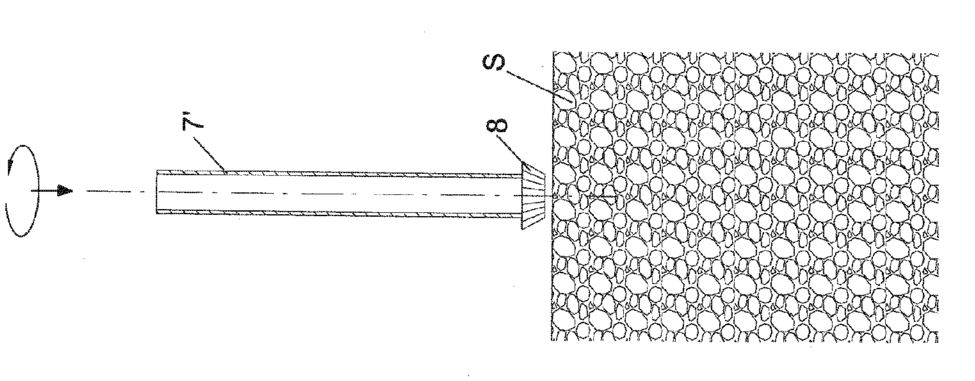


Fig.5

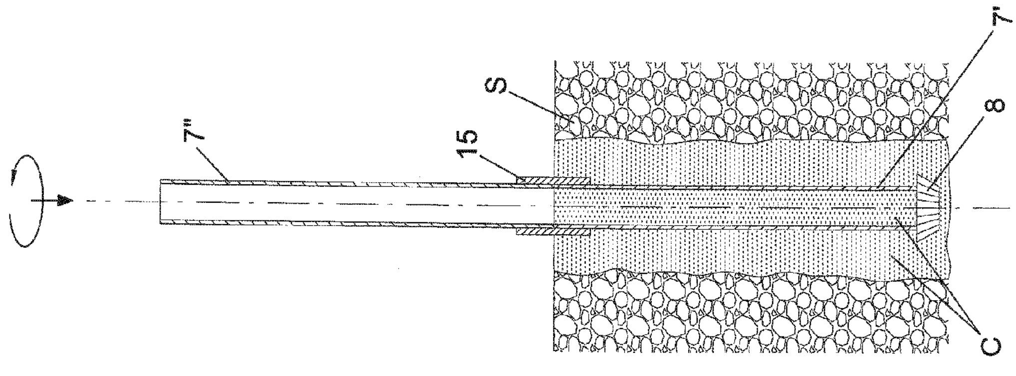


Fig.6

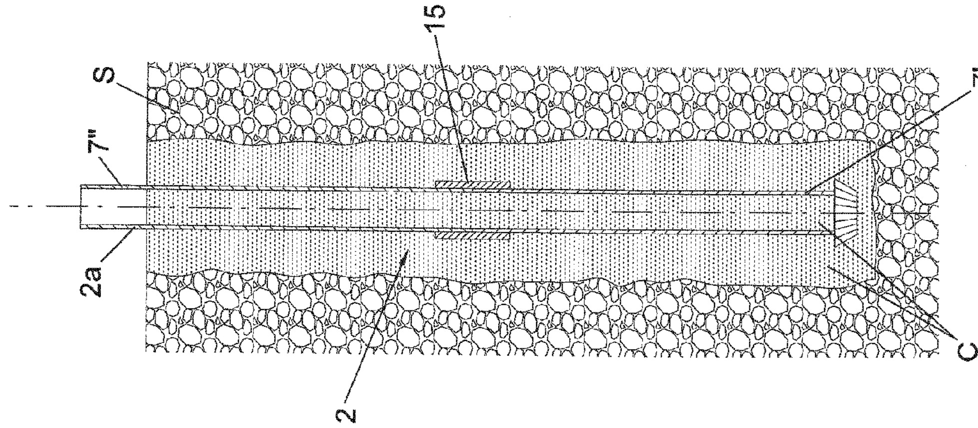


Fig.7

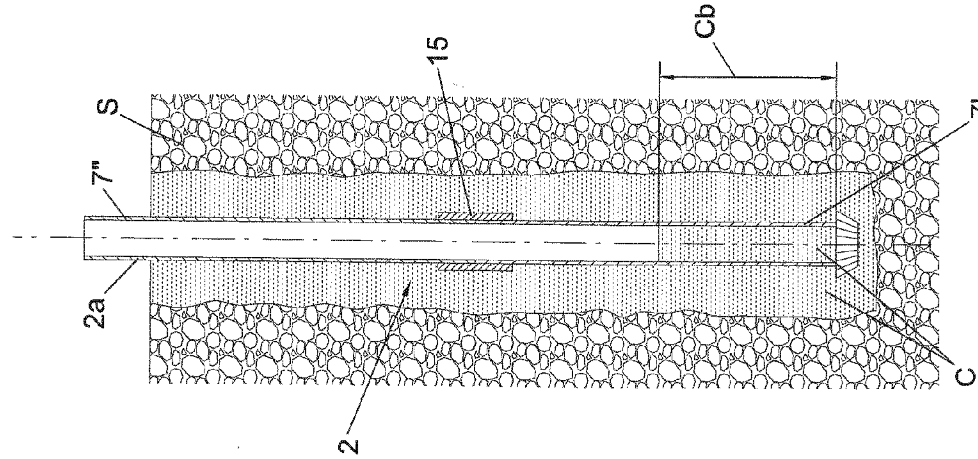


Fig.7a

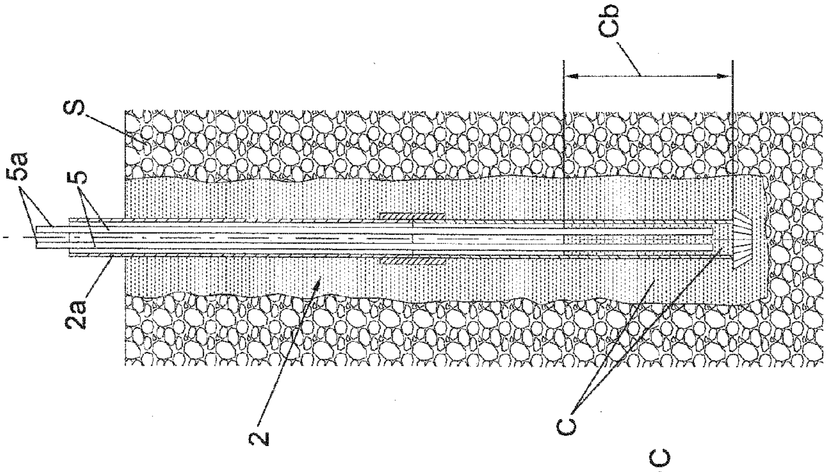


Fig.9a

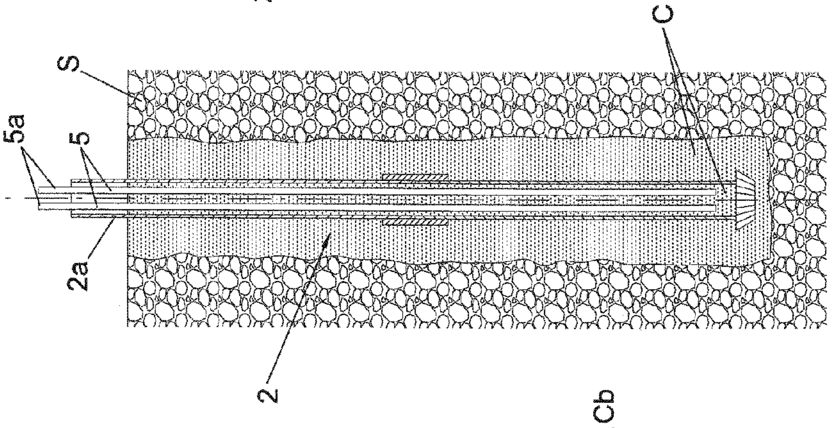


Fig.9

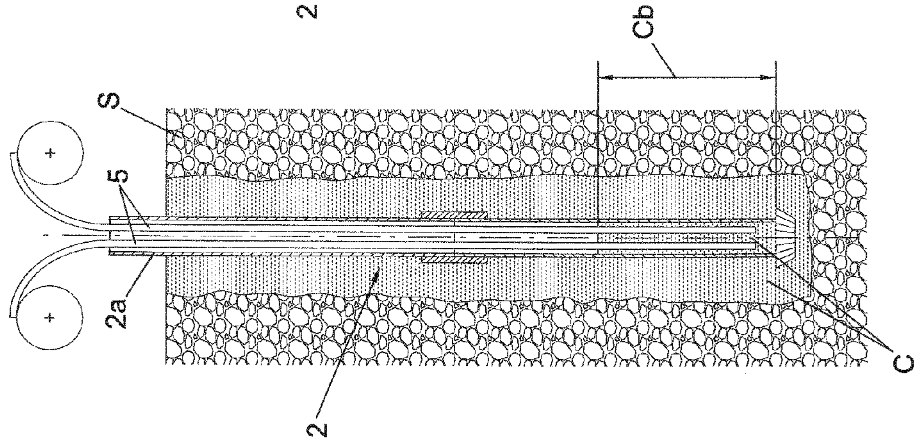


Fig.8a

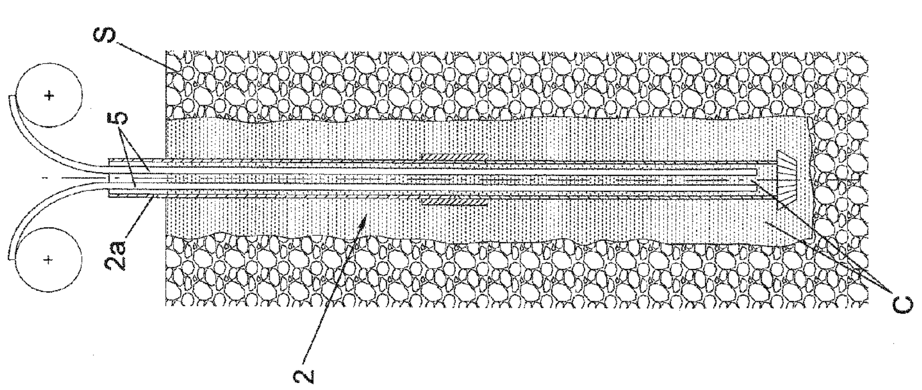


Fig.8

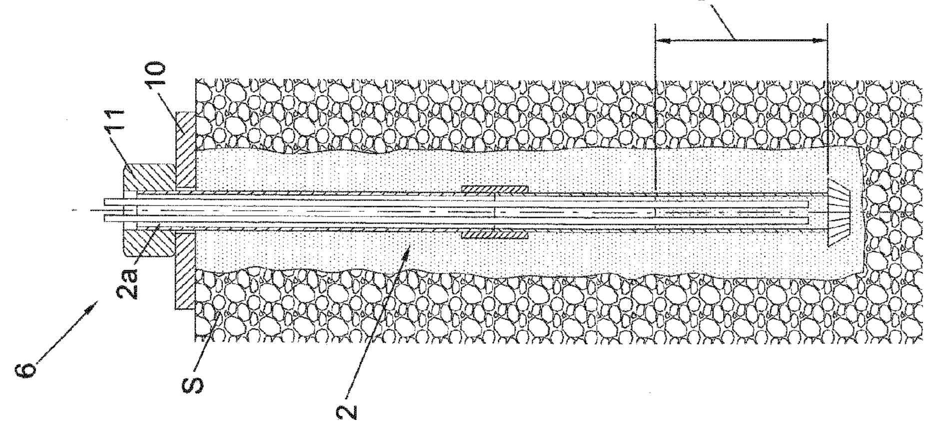


Fig.10

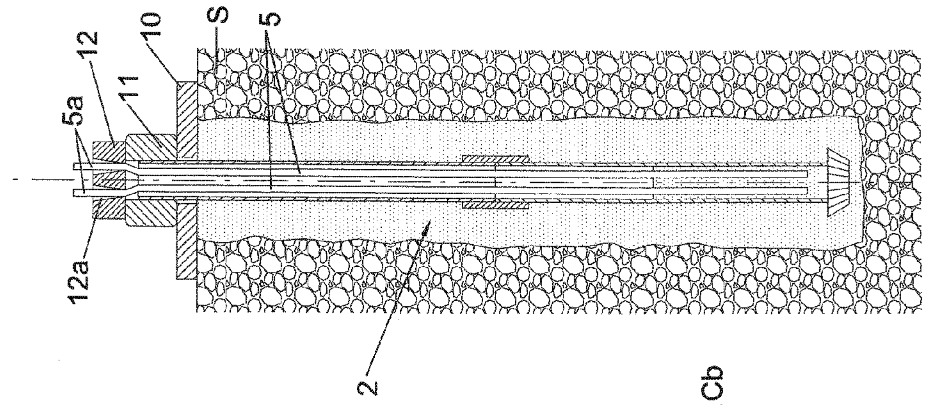


Fig.11

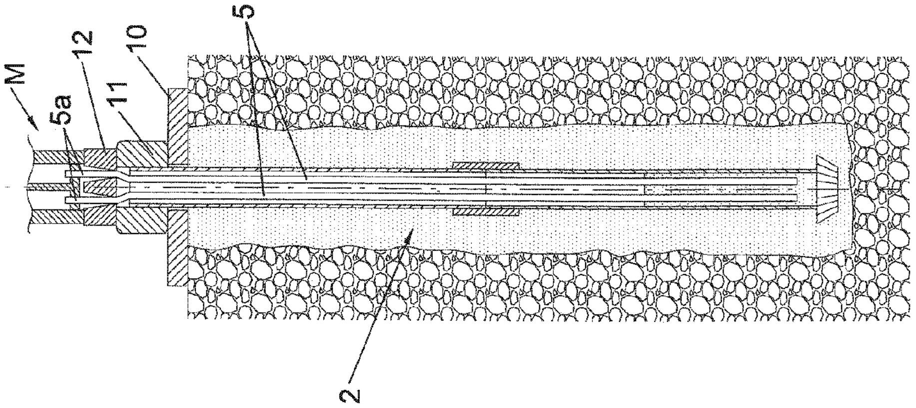


Fig.12

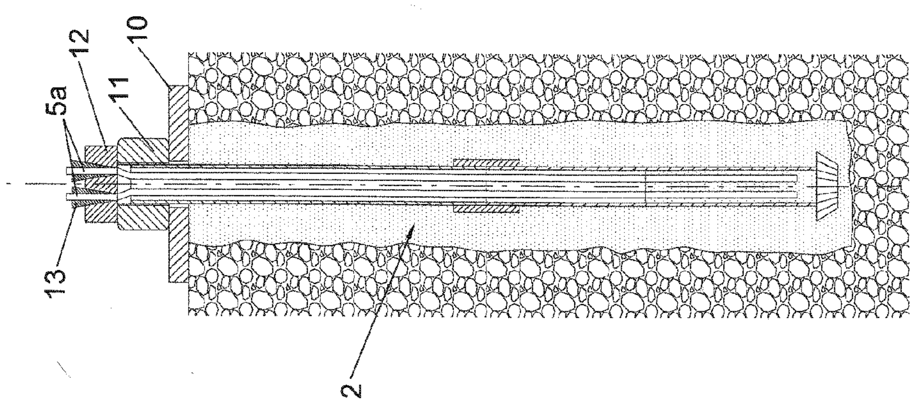


Fig.13

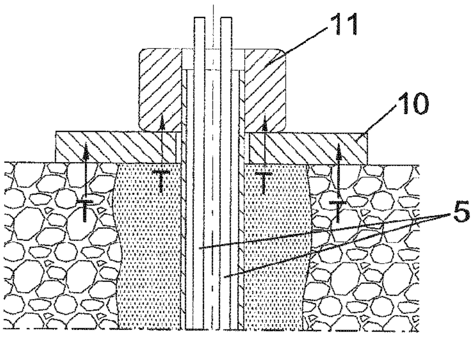


Fig.14

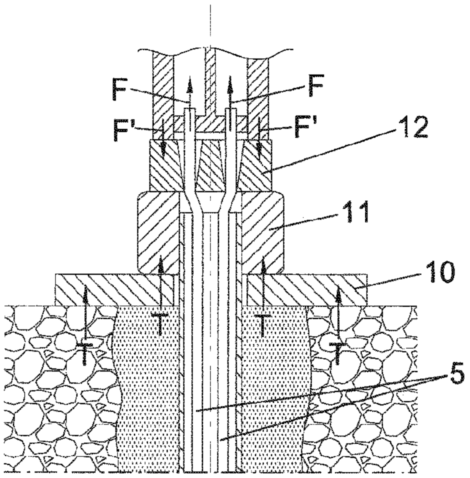


Fig.15

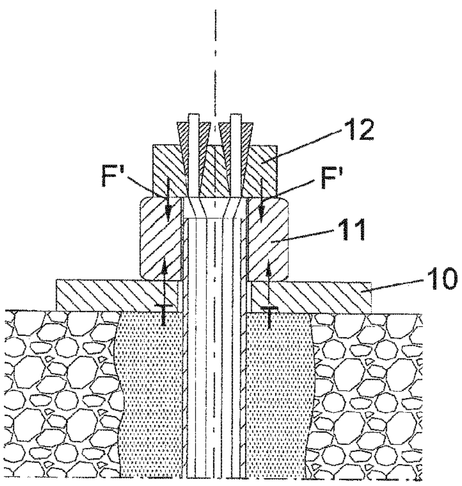


Fig.16

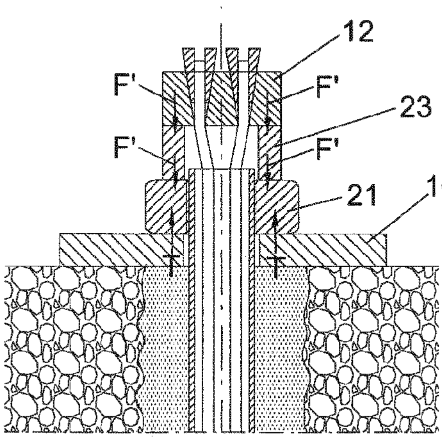
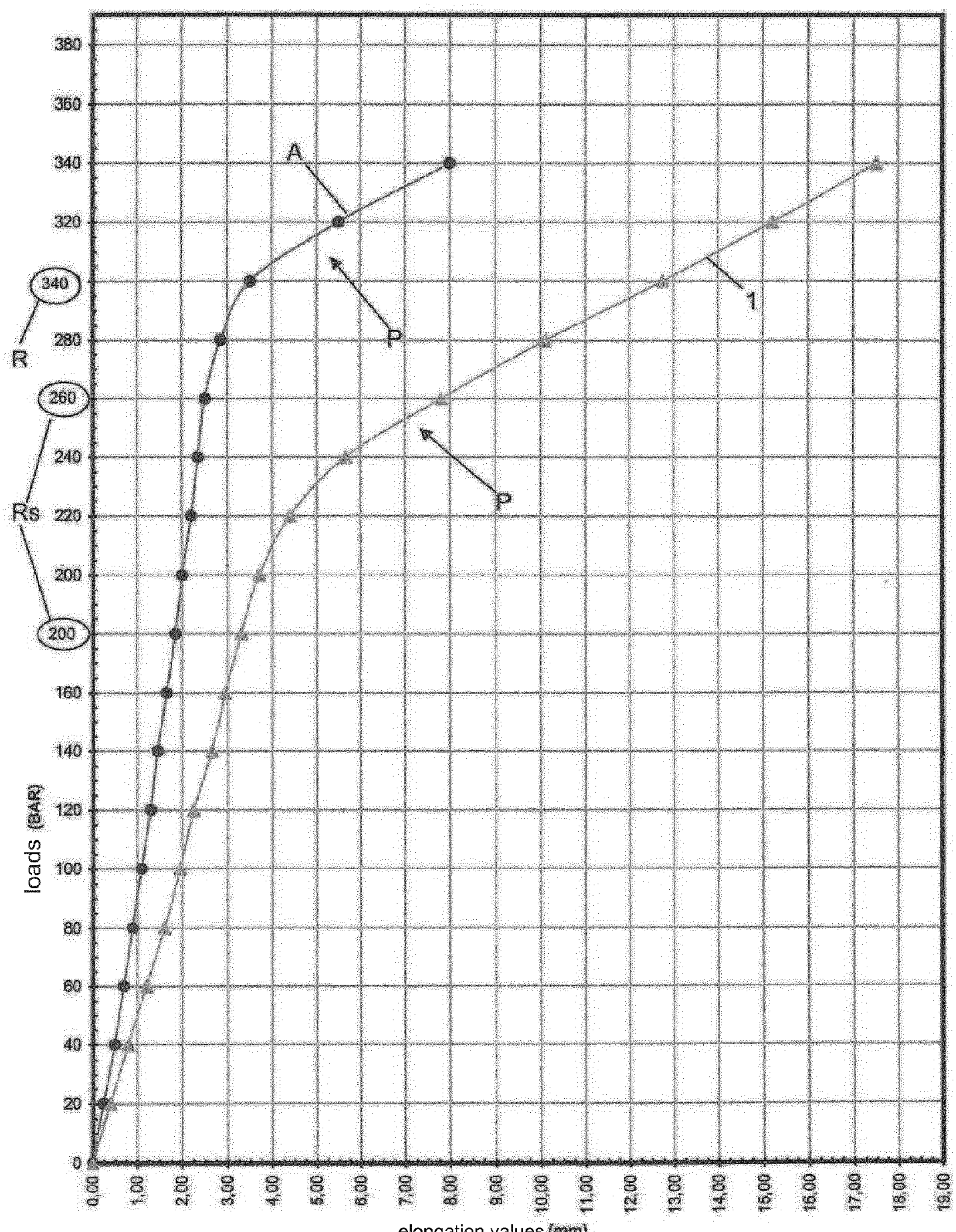


Fig.17



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200
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340
320
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360
380
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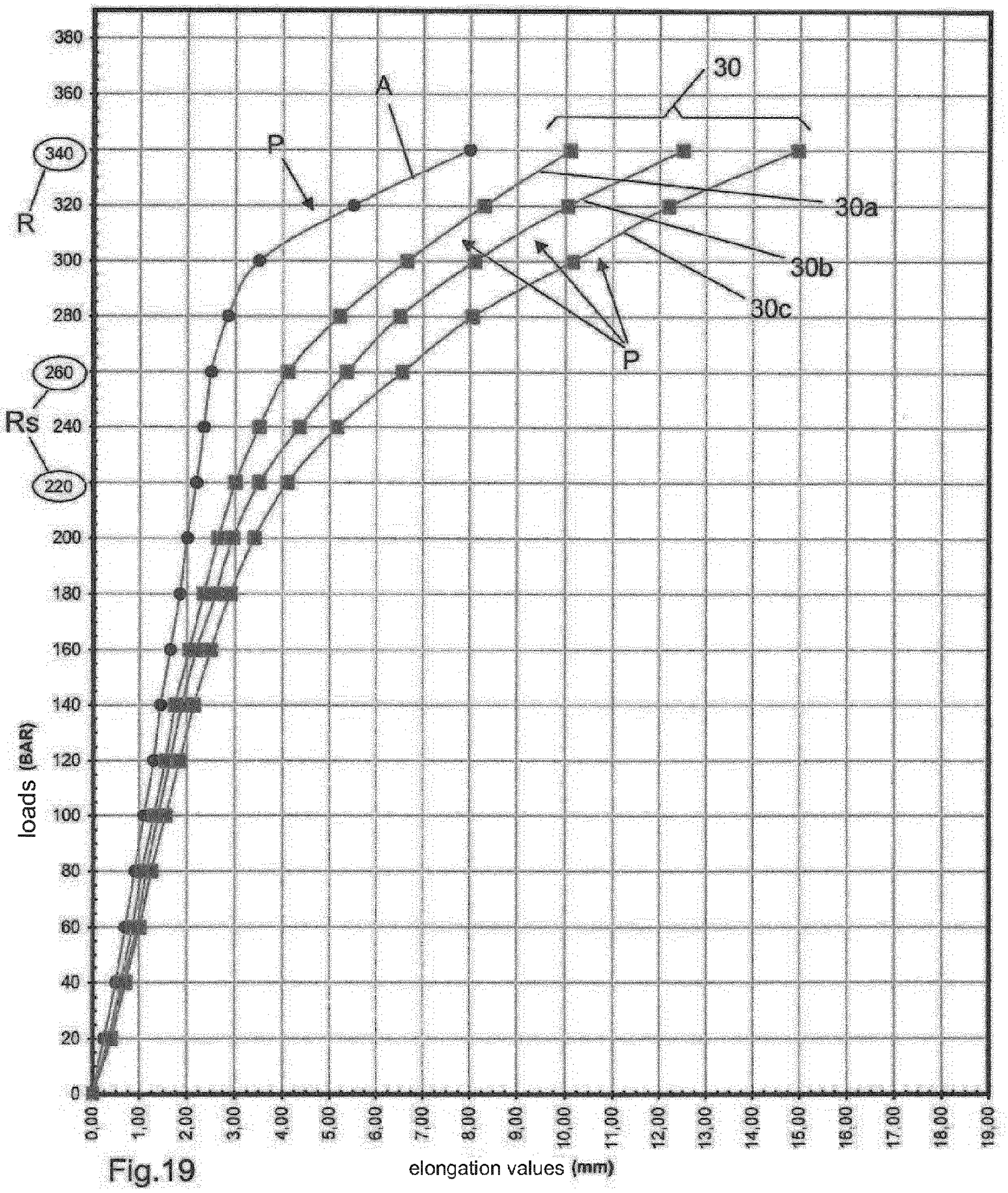
elongation values (mm)

Fig.18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80
60
40
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0
loads (BAR)
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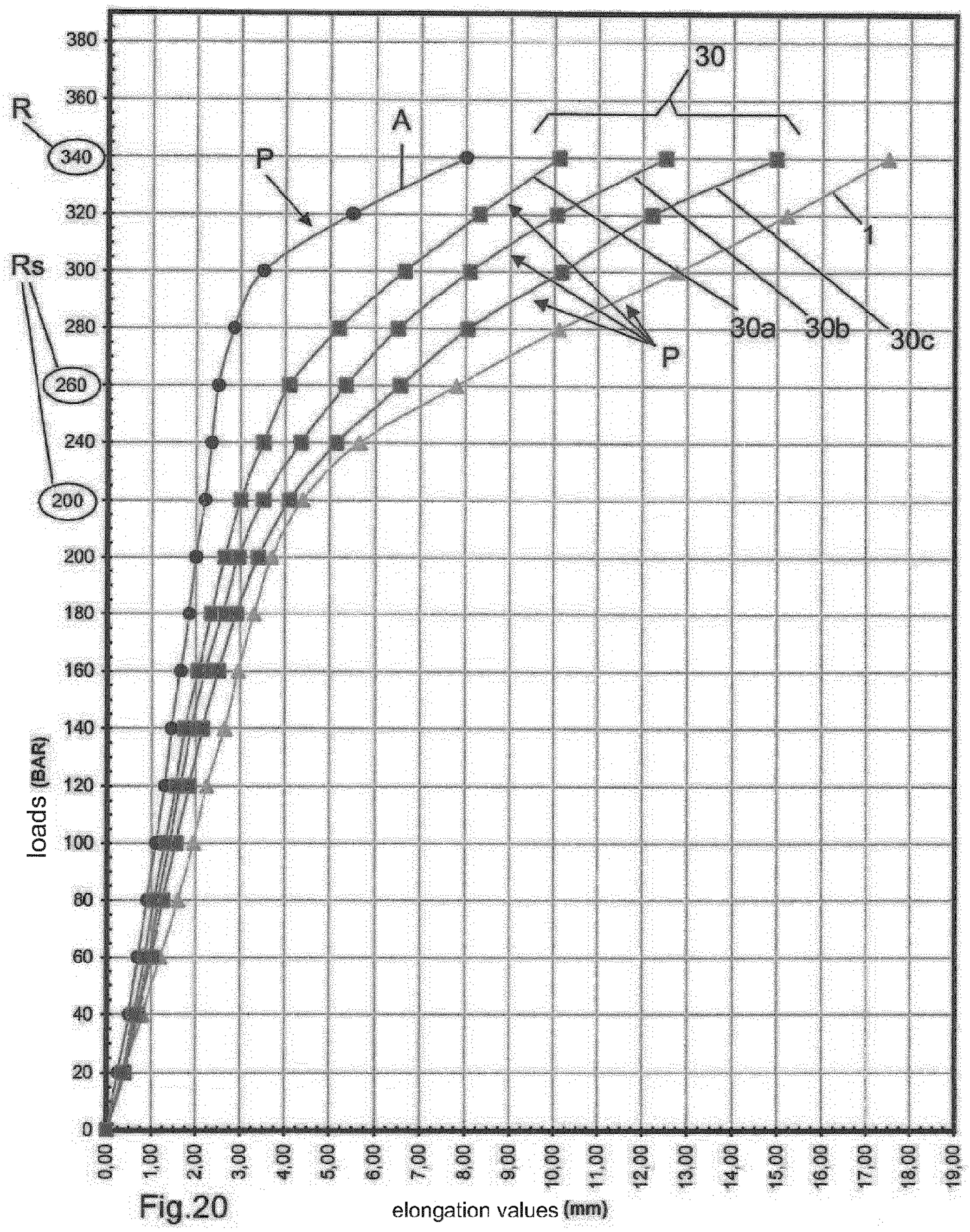
elongation values (mm)
Fig.19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elongation values (mm)

Fig.20

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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