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(54) **Method for preventive consolidation of the soil for underground minings**

Verfahren zur präventiven Konsolidierung des Bodens beim Untertagebau

Méthode pour la consolidation préventive du sol dans l'industrie minière souterraine

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(73) Proprietor: **TREVI S.p.A.**
I-47023 Cesena (Province of Forli) (IT)

(72) Inventor: **Trevisani, Davide**
I-47023 Cesena (Forli) (IT)

(74) Representative: **Lotti, Giorgio**
c/o Ing. Barzanò & Zanardo Milano S.p.A.
Corso Vittorio Emanuele II, 61
10128 Torino (IT)

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- **PATENT ABSTRACTS OF JAPAN, vol. 6, no. 45 (M-118)[923], 20th March 1982;& JP-A-56 159 417 (GISUKE EBINE) 08-12-1981**
- **PATENT ABSTRACTS OF JAPAN, vol. 9, no. 282 (M-428)[2005], 9th November 1985; & JP-A-60 123 616 (TAISEI KENSETSU K.K.) 02-07-1985**

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The file contains technical information submitted after the application was filed and not included in this specification

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Description

The object of the present invention is a method for preventive stabilisation of the soil for underground minings by means of the so-called techinique of the protective umbrella, in particular for unstable kinds of soil.

Among the present techniques for the preventive stabilisation of underground minings in particularly unstable soil, there is one known as the "protective umbrella", which consists of inserting into the soil arrays of steel tubes provided with nonreturn valves for executing injections of stabilising and consolidating mixtures, mainly cement grout.

The tubes are disposed like an umbrella, protecting the vault of an intended tunnel excavation so as to allow excavation of parts of it within a limited length. The excavation of the parts of the tunnel is alternated with the execution of said umbrellas of steel tubes that is combined with the soil stabilising injections.

The technique that is normally used comprises a phase in which the soil is drilled with a temporary and recoverable steel tubular casing; in a second phase a steel tube is fitted inside the casing. This tube is provided with holes at regular intervals and has elastic sleeves, in correspondence of each hole, that act as nonreturn valves when the stabilising mixtures are injected through the tube. A following phase is that of the recovery of the provisory casing, after which a grout sheating is formed, having a controlled maximum compressive strength, for sealing the injecting tube into the soil. In the end, the stabilising mixtures are injected into the soil, through the holes of the tube, breaking the sheating.

An alternative technique is to execute the provisory casing with the techiniques used for carrying out jet-grouting columnar treatments, that form columns of consolidated soil by injecting high pressurized grout mixtures by means of a tubular rod provided with nozzles for letting the mixture out and with a piercing bit that is made to rotate and is extracted and pushed into the ground with a controlled speed.

Traditional jet grouting is used to execute substantially vertical columns by drilling the soil by means of a hollow drill pipe having a piercing bit at its bottom end and a plurality of nozzles proximate thereto. After drilling operations are completed, grout injection is carried out in an ascending phase, beginning from the bottom of the borehole. The jet grouting technique cannot be employed conveniently for executing substantially horizontal columns because problems arise if the grout feeding is interrupted due to drill pipe damages or substitution of parts. The walls of the hole tend to collapse rather easily, owing to the fact that the grout in a substantially horizontal borehole cannot sustain the walls as it does in vertical boreholes.

Moreover, as the function of the consolidated columns is to temporarily sustain the soil above them while a tunnel is dug out underneath, the columns must be reinforced to resist shear and bending stresses that occur when archings are placed underneath them.

According to the known technique of drilling first and then injecting from the bottom of the borehole, the metal reinforcement can be fitted only when the column is formed. Two alternative methods can be used:

- a reinforcing steel tube is inserted as soon as the column is completed, therefore the tube will tend to move, because if its weight, to the lower part of the semi-solid column and it will not be coaxial with respect to it;
- the reinforcing tube is inserted in the column when this is already stiff, after having drilled the centre of the column; then it should be sealed by injecting additional grout.

All of the above identified inconveniences, that render horizontal jet grouting impractical, expensive, slow or even dangerous, are avoided by using a method according to this invention, in which the grout injection is executed advancing, simultaneously with drilling operations. In this case an outer hollow tube protects hollow grout delivering rods and guarantees an annular space therebetween through which the grout can flow out. Borehole wall collapses have therefore no influence on the operations, whatever kind of soil is being drilled.

Moreover, to reinforce the column it is enough to extract only the rods, leaving the outer tube inside the column and exactly in the centre of it.

Document JP-A-58-228558 discloses a method in which a borehole is excavated first, and after that, a planking pipe is installed in the hole. Then, a grout pipe with packings is inserted inside the planking pipe. The packings are then inflated and a grout is injected at low pressure through the grout pipe and discharge holes of the planking pipe so as to fill the space between the excavated hole and the planking pipe. Finally, the grout pipe is pulled off, and the planking pipe is filled with mortar. This method suffers from the above drawbacks, and is not suitable for high pressure grout injections.

Document JP-A-55-64395 relates to a method for executing vertical reinforcing concrete pillars by means of an apparatus that comprises a hollow grout delivering shaft having a bottom excavating blade. The shaft is located inside a cylinder having a bottom agitating blade and both the shaft and the cylinder are rotated in opposite directions. This method is not suitable for executing substantially horizontal columns that are required for tunnelling with the protective umbrella technique.

Document DE-A-3447872 disdoses a soil stabilising method for tunnelling in which a plurality of boreholes are obtained in the soil about an arc of a circle outlining a tunnel that has to be dug out. A tube provided with valves and surrounded by a jute bag is slipped in each borehole, and an injection packer is inserted in each tube for injecting a fluid mixture that fills the bag, presses the walls of the borehole and infiltrates in the

surrounding soil. The fluid mixture in the bag and the portion that has penetrated in the soil consolidates and stabilises the soil. Also this method suffers from the same inconveniences as JP-A-58-228558, and is incompatible with high pressure grout injections.

It is an object of this invention to provide a method for stabilising the soil for tunnel excavations capable of overcoming the above inconveniences.

These and further objects and advantages, which will be more apparent hereinafter are attained by using a method according to Claim 1.

The details of this invention will appear more clearly from the detailed specification of a favourite form of execution of the process for tunnel excavations that is illustrated in the enclosed drawings, in which:

fig. 1 shows a phase of the present process;
fig. 2 shows a phase following the phase of fig. 1.

With reference to figs. 1 and 2, for carrying out the process, a straight metallic hollow tube 1, preferably made out of steel, and a straight hollow rod 2 are used. Said rod has a diameter that is smaller than the one of the tube 1 and a double rotary drilling unit, which is not shown in the figures, is used to rotate both the tube 1 and the rod 2.

The rod 2 is provided at one end with a boring tool indicated as a whole with 3 which comprises a traditional piercing bit 4 and near this there are nozzles that are distributed radially on the rod and that communicate with the outside. The tools that are hereby mentioned are not described in details, as they are traditional and already known.

In operating conditions, the rod 2 is slipped into the tube 1 and is kept coaxial with respect to the tube by the rotary drilling unit.

The boring tool 3 is positioned and kept outside the front end of the tube and is directed perpendicular to the soil that has to be stabilised. The rod 2 and the tube 1 are both rotated by the rotary drilling unit for piercing the soil and proceed this way. The rotary drilling head forces the rod 2 and the tube 1 to rotate at the same time but in the opposite directions of rotation. For example the rod 2 is rotated clockwise while the tube 1 is being rotated counter-clockwise.

The material that is excavated by the drilling operation is conveyed towards the outside through the annular hollow space 5 between the rod 2 and the inner annular surface of tube 1.

Simultaneously to the proceeding of the tube 1 and the rod 2 in the soil, high pressurized liquid mixture is injected through the rod, removing the finest part of soil. The mixture flows through the nozzles forming a column 6 of soil and grout mixture around the tube 1 that later on will stiffen.

When the right length of the column 6 is obtained, the rod 2 has to be pulled out of the tube 1 and taken away whereas the tube 1 may be left in the soil so to form columns of reinforced soil.

In a preferred form of realization of the first phase of the piercing process, the tube 1 and the rod 2 are forced to advance and spin according to prefixed parameters in a direction substantially oblique compared with the level line so that columns are formed in such a way that they partially lie one over the other like the scales of a fish.

As it can be observed, the process that has been described cuts off some phases of the traditional process establishing a column of consolidated soil in a shorter time.

Claims

1. A method for stabilising the soil for tunnel excavations by inserting into the soil arrays of steel tubes for the injection of grout about an intended tunnel excavation,
characterised in that it comprises the steps of:

   - locating a said hollow tube (1) at an excavation site;
   - positioning a hollow rod (2) with nozzles co-axially within said hollow tube (1) wherein an annular space (5) is defined between the rod (2) and the tube (1), the hollow rod being fitted with a boring tool (3) at one end thereof;
   - rotating the hollow tube (1) and the hollow rod (2) for excavating material from said excavation site by means of said boring tool (3);
   - simultaneously injecting a high pressurised liquid mixture through said hollow rod (2) into said excavation site through radially positioned nozzles proximate to the boring tool during rotation of the hollow tube (1) and the hollow rod (2) thereby increasing the diameter of the excavation, wherein a portion of the finest part of the excavated soil is removed from the excavation site via said annular space (5) and said liquid mixture admixes with the remaining portion of the excavated material for forming a stiffening column (6) of soil and liquid mixture around the tube (1) behind the boring tool as it progresses into the soil; and
   - removing said rod (2) from the hollow tube (1) subsequent to achieving the desired length of column (6).

2. A method according to Claim 1, characterised in that during excavation the tube (1) and the rod (2) are forced to proceed simultaneously and are rotated in opposite directions.

Patentansprüche

1. Verfaren zum stabilisieren des bodens zur Tunnelasschachtung durch Einbringen von Gruppen von Stahlrohren mit Ventilen in den Boden zum Injizieren von Zement in den Boden um die beabsichtigte Tunnelausschactung
dadurch gekennzeichnet, daß

   - ein hohles Rohr (1) an einer Ausschachtungsstelle angeordnet wird;
   - eine hohle Stange (2) mit Düsen koaxial in dem hohlen Rohr (1) angeordnet wird, so daß ein ringförmiger Zwischenraum (5) zwischen der Stange (2) und dem Rohr (1) gebildet wird, wobei in die hohle Stange eine Bohrwerkzeug (3) an deren einem Ende eingesetzt wird;
   - das hohle Rohr (1) und die hohle Stange (2) gedreht werden, um Material aus der Ausschactungsstelle mittels des Bohrwerkzeug (3) auszuschachten;
   - ein Hochdruck-Flüssiggemisch durch die hohle Stange (2) in die Ausschachtungsstelle nahe dem Bohrwerkzeug (3) während der Drehung des hohlen Rohres (1) und der hohlen Stage (2) durch radial verteilten Düsen, gleichzeitig injiziert wird, so daß der Durchmesser der Ausschachtungsstelle verbreitet und der ein Teil des feinkörnigsten Anteils des ausgebaggerten Bodens aus der Ausschachtungsstelle über den ringförmigen Zwischenraum (5) entfernt wird, und das Flüssiggemisch mit dem verbleibenden Anteil des ausgeschachteten Materials vermischt wird, um eine erhärtende Säule (6) des Bodens und des Flüssiggemisches, um das Rohr (1) hinter dem Bohrwerkzeug während der Bohrvorgang in dem Boden, zu bilden; und
   - eine Stange (2) aus dem hohlen Rohr (1), nach der Erreichung der gewünschten Länge der Säule (6), entfernt wird.

2. Verfahren nach Anspruch 1,
dadurch gekennzeichnet, daß
während des Ausschachtens das Rohr (1) und die Stange (2) gleichzeitig vorgerückt und in entgegengesetzten Richtungen gedreht werden.

Revendications

1. Procédé pour stabiliser le sol dans des excavations de tunnels, dans lequel on enfonce dans le sol des rangées de tubes d'acier équipés de vannes pour injecter du mortier dans le sol autour d'une future excavation de tunnel, caractérisé en ce qu'il comprend les phases consistant à:

   - placer un tube creux (1) avec des buses dans un site d'excavation;
   - positionner une tige creuse (2) coaxialement dans le tube creux (1), un espace annulaire (5) étant défini entre la tige (2) et le tube (1), et ledit tube creux étant muni à une de ses extrémités d'un outil de forage (3);
   - faire tourner le tube creux (1) et la tige creuse (2) pour creuser le matériau di site d'excavation à l'aide desdits moyens de forage (3);
   - injecter simultanément un mélange fluidique sous houte pression dans le site d'exavation, par ladite tige creuse (2), a travers les buse réparties radialement, à proximité des moyens de forage (3) pendant la rotation du tube creux (1) et de la tige creuse (2), en élargissant par cela le diamètre de l'excavation, une partie de la fraction la plus fine du sol creusé étant évacuée du site d'excavation par ledit espace annulaire (5), et ledit mélange liquide se mélangeant avec la partie restante du matériau creusé pour former une colonne (6) de sol et de mèlange liquide qui se solidifie autour du tube (1) derrière l'outil de forage, pendant sa progression dans le sol; et
   - extraire ladite tige (2) du tube creux (1) aprés qu'il a obtenu la longueur voulue de la colonne (6).

2. Procédé selon la revendication 1, caractérisé en ce que, pendant l'excavation, le tube (1) et la barre (2) sont contraints à avancer simultanément, tout en étant mis en rotation en sens inverse l'un de l'autre.

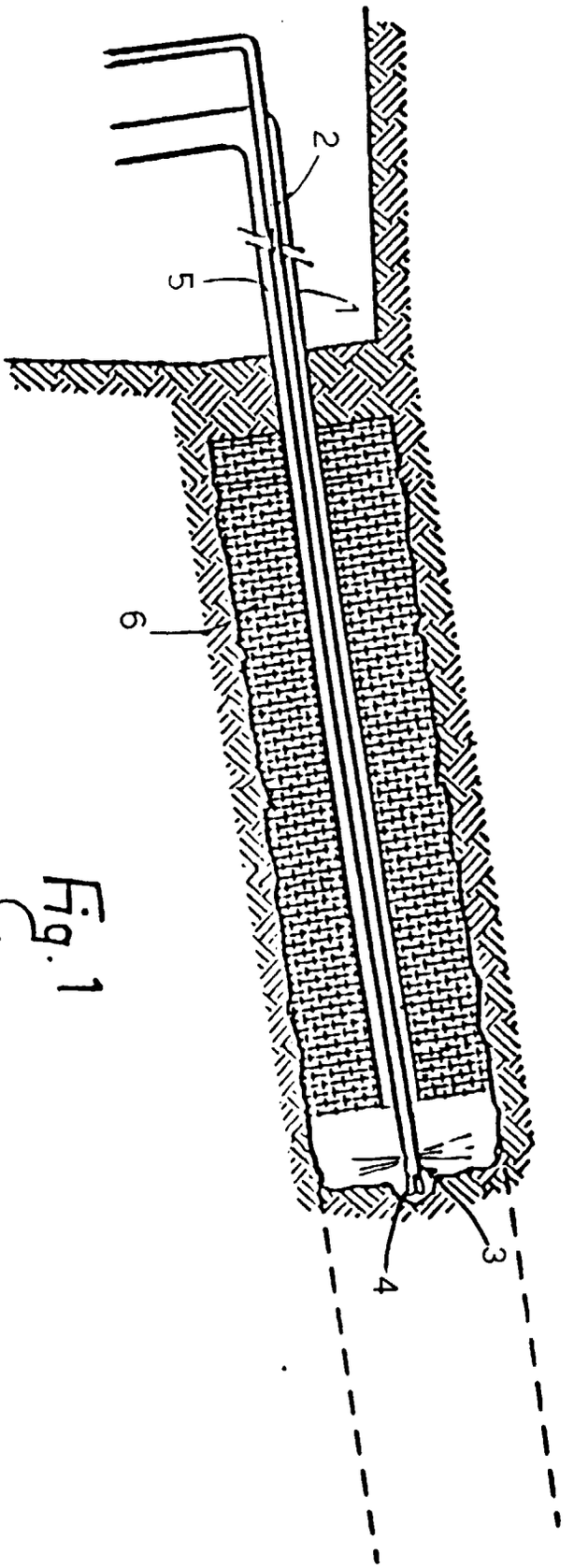

Fig. 1

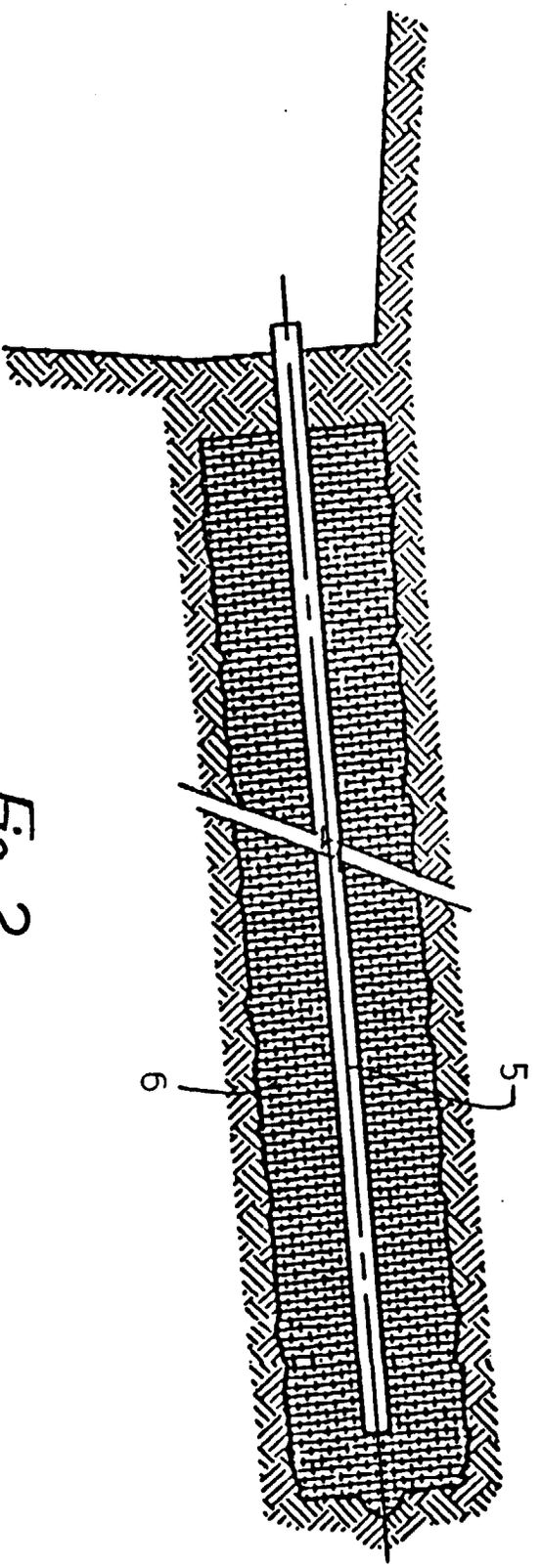

Fig. 2