

(19)



Europäisches Patentamt
European Patent Office
Office européen des brevets



(11)

EP 0 897 050 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
15.01.2003 Bulletin 2003/03

(51) Int Cl.7: **E21D 9/06**, E21D 11/10,
E21D 9/08

(21) Application number: **97202520.9**

(22) Date of filing: **14.08.1997**

(54) **Method of building a lined tunnel**

Verfahren zum Herstellen eines bekleideten Tunnels

Procédé de construction d'un tunnel à revêtement

(84) Designated Contracting States:
BE DE DK FR GB IT NL

(43) Date of publication of application:
17.02.1999 Bulletin 1999/07

(73) Proprietor: **I.T.M. Industriële Tunnelbouw
Methode C.V.
2961 AG Kinderdijk (NL)**

(72) Inventors:
• **Noorlander, Nicolaas
3343 CV Hendrik Ido Ambacht (NL)**

• **van Oosteren, Kees
3038 AB Rotterdam (NL)**
• **van der Sloot, Marco
3085 GA Rotterdam (NL)**

(74) Representative:
**Iemenschot, Johannes Andreas, Ir. et al
Exter Polak & Charlouis B.V.,
P.O. Box 3241
2280 GE Rijswijk (NL)**

(56) References cited:
DE-A- 2 932 430 DE-A- 4 001 949
GB-A- 2 057 035 GB-A- 2 146 371

EP 0 897 050 B1

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

[0001] The invention relates to a method of building a lined tunnel according to the preamble of claim 1.

[0002] Such a method, known as the extruded concrete lining (ECL) method, is disclosed in document GB-A-20 57 035. The supporting structure comprises ringshaped elements. The outer surface of the ring shaped elements is provided with circumferential ribs protruding into the lining material to increase the grip between the support structure and the tunnel lining. The ring shaped elements may also be provided with longitudinal ribs. The ribs on the support structure form grooves in the tunnel lining along which cracks can occur so that the tunnel lining can follow settlements of the surrounding earth. The location of the grooves in the tunnel lining formed by the ribs is determined by the support structure. Due to the dimensions of the ring shaped elements the distance between the circumferential ribs is relatively short.

[0003] The object of the invention is to provide an improved method of building a lined tunnel of the type mentioned at the beginning (extruded concrete lining method) which results in a tunnel lining which is watertight over the full length of the tunnel.

[0004] This object is achieved with a method according to claim 1.

[0005] With the method according to the invention the distance between the separation means, in particular in longitudinal direction of the tunnel lining, can be chosen such that the length of the separate sections of the tunnel lining is adapted to the friction between the tunnel lining and the surrounding earth.

[0006] The sections as such are watertight. Only the gaps between the sections of tunnel have to be provided with sealing means. Moreover, the tunnel lining can follow settlements.

[0007] Preferred embodiments of the method according to the invention are claimed in the dependent claims.

[0008] The invention will now be explained in the description of preferred embodiments of the method according to the invention with reference to the drawings, wherein:

Fig. 1 is a schematic longitudinal section of the front part of a lined tunnel with an excavating machine showing the method according to the invention,

Fig. 2 is a schematic representation of a tunnel lining with separation means,

Fig. 3 shows the tunnel lining of Fig. 2 after hardening of the tunnel lining,

Fig. 4 shows separation means in a tunnel lining in the form of grooves,

Fig. 5 shows separation means in a tunnel lining in the form of ringshaped separation elements,

Fig. 6 a schematic representation of a tunnel lining with longitudinally and circumferentially extending separation means,

Fig. 7 a schematic representation of a tunnel lining with helically extending separation means.

[0009] Fig. 1 shows schematically the front part of a tunnel 1 in surrounding earth 2, the tunnel 1 being provided with a lining 3.

[0010] When building the tunnel 1 a tunnel is excavated in the earth 2 by means of a forward moving excavating or boring machine 4. Such a boring machine 4 may of any type known in the art and does not need any further explanation. In the region immediately behind the boring machine 4 the earth 2, which may be unstable, is supported by a shield 5 which is connected to the boring machine.

[0011] Behind the boring machine 4 a support structure 6 is placed in the excavated tunnel. Usually the support structure 6 is built up from support elements 7 placed behind one another.

[0012] Between the support structure 6 and the surrounding earth which may be covered by the shield 5, a ringshaped gap 8 is formed. At the front end of the support structure 6 a sealing means 9 is provided between the support structure 6 and the shield 5 sealing off the gap 8 towards the boring machine 4. The ringshaped gap 8 is filled with concrete by injecting liquid concrete into the gap 8. The liquid concrete may be supplied by a concrete pump 10 with pumps the liquid concrete from a reservoir 11 through a conduit 12 extending through the sealing means 9 into the gap 8.

[0013] The concrete in the gap 8 is supported by the support structure 6 and is kept under pressure in that the sealing means 9 is connected to the boring machine 4 by means of hydraulic cylinders 13 which transfer at least part of the axial force exerted on the boring machine 4 to the concrete in the gap 8.

[0014] The concrete in the gap 8 is allowed to solidify whereafter further support by the support structure is not necessary anymore.

[0015] Usually the support structure 6 moves with the boring machine 4 in that after the boring machine 4 has moved over a certain distance, the support element 7' at the rear end of the support structure 6 is placed in front of the support element 7" at the front end of support structure 6.

[0016] It is however also possible that the support elements remain in place and become part of the tunnel lining. In this case a new support element will be placed at the front end of the support structure after the boring machine has moved over a certain distance.

[0017] The solidified concrete is finally allowed to harden, thus forming the final tunnel lining 3.

[0018] The method described so far is known as the extruded concrete lining (ECL) method. The method is also described in document GB-A-2 057 035.

[0019] When ordinary, preferably fibre-reinforced concrete is used as material for the tunnel lining, the concrete will shrink during hardening, which will lead to tensile stresses and the occurrence of cracks in the tun-

nel lining. As mentioned earlier cracks can also occur as a result of settlement of the surrounding earth. The result of cracks is that the tunnel lining is not sufficiently watertight anymore. As the location of the cracks can normally not be predicted, the tunnel lining has to be provided with watertight means over its entire length.

[0020] With the method according to the invention the uncontrolled forming of cracks in the tunnel lining is prevented.

[0021] Before hardening of the concrete, separation means are provided in the tunnel lining so that the tunnel lining is divided into separate sections. Fig. 2 shows schematically a part of a tunnel lining. The separation means are indicated with 14 and the ringshaped sections with 15. The separation means 14 extend in circumferential direction such that ringshaped sections 15 are formed with a length L1. The length of the sections 15 is chosen such that each section 15 is free to shrink in axial direction during hardening of the concrete. Free to shrink means that the tensile stresses in the concrete are negligible or sufficiently low so as to prevent the initiation of cracks in the concrete. The length L1 depends on the friction between the tunnel lining and the surrounding earth. The friction can be decreased by greasing e.g. injection of bentonite. The friction may already be low by virtue of beneficial properties of the surrounding earth.

[0022] When the sections 15 of the tunnel lining 3 shrink the length of the sections will decrease to L2 as shown in Fig. 3. Gaps between the sections 15 which are indicated with 16 in Fig. 3 have to be bridged by sealing means in order to obtain a watertight tunnel lining.

[0023] A tunnel lining which is divided into separate sections which are connected to one another through more or less flexible sealing means can also follow settlements of the surrounding earth, so that the formation of cracks as a result of settlements of the surrounding earth is also prevented.

[0024] There are several ways of providing separation means in the tunnel lining 3.

[0025] It is possible to provide weakened areas on predetermined places in the tunnel lining 3 such that cracks in the tunnel lining occurring as result of shrinkage of the hardening tunnel lining will only form in the weakened areas. In this way the tunnel lining is divided into separate sections.

[0026] As shown in Fig. 4, weakened areas may be provided by making grooves 17 (e.g. circumferential grooves) in the solidified but not yet hardened tunnel lining 3. The grooves between the separate sections are filled with a sealing means 18.

[0027] It is also possible (Fig. 5) to insert separation elements 19 (e.g. rings) on predetermined places in the tunnel lining 3. These separation elements 19 may be inserted during injection of the liquid concrete for the tunnel lining or thereafter but before the concrete is solidified. The separation elements may extend over a part

(as shown in Fig. 5) of or the whole radial thickness of the tunnel lining. In the former case the remaining part of the radial thickness of the tunnel lining may be considered as a weakened area in which a crack will occur during hardening of the tunnel lining. In the latter case separate sections are already formed upon insertion of the separation elements. The separations may have any configuration e.g. stright, inclined, curved, S- or Z shaped.

[0028] In a preferred embodiment the separation elements comprise the sealing means between the sections of the tunnel lining.

[0029] In case the sealing means have to be able to follow the decrease of the length of the adjacent sections of the tunnel lining during hardening and/or imposed settlements, the sealing means should have spring characteristics or be combined with separate spring means.

[0030] A sealing means with spring characteristics or a combination of sealing means and spring means may be designed in several different ways (see e.g. Norbert Klawe and Alfred Haack: Tiefbaufugen - Fugen- und Fugenkonstruktionen in Beton- und Stahlbetonbau).

[0031] The spring characteristics of the sealing means or the combination of sealing means and spring means may be such that a compression force is maintained in the sections of the tunnel lining during hardening. In this case the length of the sections of the tunnel lining may be increased with respect to the situation wherein no additional axial force is exerted on the section during hardening.

[0032] A remaining compression force in the sections of the tunnel lining can also be achieved by applying active compression means in combination with the sealing means. An example of such active compression means is shown in EP-A-0 021 702. The active compression means may also comprise wedges or jacks, controlled by manpower or a power unit.

[0033] Unequal radial loadings on the tunnel lining will cause bending moments in the lining. For an extensive discussion of the loading on tunnel lining and the corresponding hoop forces, bending moments and radial displacements reference is being made to a publication by H. Duddeck and J. Erdmann "Structural design models for tunnels", published in Tunneling '81, the Institute of Mining and Metallurgy, pag. 83-91, 1981. The bending moments in the full circular lining may together with the hoop stresses have a significant impact on the required thickness of the lining if longitudinal cracking of that lining is to be avoided.

[0034] In certain earth conditions however it may be allowable that where the highest bending moments occur the lining will crack longitudinally and that the lining will elliptically deform within certain limits until a new equilibrium of forces is obtained.

[0035] Allowing for such a behaviour may result in a reduction of the required lining thickness and a corresponding reduction in costs. For quality control however

it is a far better option not to rely on spontaneous cracking but to provide the tunnel lining with longitudinally extending separation means thus dividing the tunnel lining in sections in circumferential direction. The gaps between these sections can be provided with sealing means to ensure watertightness of the total lining. The longitudinal extending separation means can be similar to the circumferentially extending separation means described above.

[0036] Of course, a tunnel lining may have both types of separation means, as is shown schematically in Fig. 6, wherein the longitudinally extending separation means are indicated with 20 and the circumferentially extending separation means with 14.

[0037] Instead of separation means extending in circumferential direction, the tunnel lining may be provided with separation means extending helically along the tunnel lining, as shown schematically in Fig. 7, wherein the separation means are indicated with 21.

[0038] The tunnel lining 3 is preferably an extruded single layer. The extrusion in one or more stages or a multilayer lining e.g. concrete with different properties is also possible. The single layer may be provided with an internal secondary layer for e.g. safety purposes (fire protection, protection against collision of cars, trams), architectural purposes or any other purpose. The secondary layer is however not essential for the tunnel lining of the invention.

[0039] If suitable materials for the secondary lining become available in the future the secondary lining may provide such a watertightness or additional watertightness that sealing means in the joints between the sections of the tunnel lining can be omitted or that the sealing properties of the sealing means may be reduced. It is also envisaged that an internal secondary lining which, as mentioned before, may be sprayed onto the single layer (primary lining) or may consist of a thin watertight sheet, might facilitate an easy movement of a sliding support structure e.g. of the type described in EP-A-0 301 188.

[0040] Usually concrete will be used for a tunnel lining. However, also other suitable materials may be used.

[0041] It will be evident for a skilled person that the present invention is not limited to the embodiment described above. Essential for the invention is that an extruded tunnel lining is divided into separate sections with sealing means between these sections.

Claims

1. Method of building a lined tunnel (1) in earth comprising the steps of excavating a tunnel in the earth by means of a forward moving excavating machine (4), placing a support structure (6) behind the excavating machine after a tunnel part has been excavated, such that a ringshaped gap (8) is formed be-

tween the support structure and the surrounding earth, providing a sealing means (9) for sealing off the ringshaped gap towards the excavating machine, filling the ringshaped gap behind the sealing means by injecting therein a liquid lining material, such as liquid concrete, and allowing the lining material to become solid and to harden, thus forming a tunnel lining (3), separation means (14; 20; 21) being provided in the tunnel lining before hardening of the lining material, so that the tunnel lining (3) is divided into separate sections, the separation means being located in such places that the separate sections are free to follow settlements of the surrounding earth, **characterized by** providing the separation means (14; 20; 21) in such places that the separate sections (15) are free to shrink during hardening of the lining material and by filling the gaps (16) formed between the separate sections with a sealing means (18).

2. Method according to claim 1, wherein the separation means (14; 20; 21) comprise weakened areas provided on predetermined places in the tunnel lining, such that cracks in the tunnel lining occurring as a result of shrinkage of the hardening lining material or following settlements of the surrounding earth will form only in the weakened areas.
3. Method according to claim 1, wherein separation means comprise separate separation elements (19) inserted on predetermined places in the tunnel lining, said separation elements extend over a part of or substantially the whole radial thickness of the tunnel lining (3).
4. Method according to claim 3, wherein the separation elements (19) comprise the sealing means between the sections of the tunnel lining.
5. Method according to claim 3, wherein the separation elements act as a spring in the direction the movements of the adjacent sections of the tunnel lining.
6. Method according to claim 3, wherein the separation means comprise active compression means.
7. Method according to anyone of claims 1 to 6, wherein the separation means (14) extend in circumferential direction of the tunnel lining.
8. Method according to anyone of claims 1 to 6, wherein the separation means (20) extend in longitudinal direction of the tunnel lining.
9. Method according to anyone of claims 1 to 6, wherein the separation means (21) extend helically along the tunnel lining.

Patentansprüche

1. Verfahren zum Bauen eines ausgekleideten Tunnels (1) in Erde, umfassend einen Schritt, bei dem mittels einer vorgetriebenen Aushubmaschine (4) ein Tunnel in der Erde ausgehoben wird, einen Schritt, bei dem hinter der Aushubmaschine, nachdem ein Tunnelteil ausgehoben worden ist, eine Stützstruktur (6) derart angebracht wird, daß ein ringförmiger Spalt (8) zwischen der Stützstruktur und der umgebenden Erde gebildet wird, einen Schritt, in dem ein Dichtmittel (9) zum Abdichten des ringförmigen Spaltes gegenüber der Aushubmaschine bereitgestellt wird, einen Schritt, in dem der ringförmige Spalt hinter dem Dichtmittel durch Einspritzen eines flüssigen Auskleidungsmaterials wie flüssigem Beton gefüllt wird, und einen Schritt, in dem dem Auskleidungsmaterial ermöglicht wird, sich zu verfestigen und auszuhärten, so daß eine Tunnelauskleidung (3) gebildet wird, wobei vor dem Aushärten des Auskleidungsmaterials ein Trennmittel (14;20;21) in der Tunnelauskleidung bereitgestellt wird, so daß die Tunnelauskleidung (3) in getrennte Abschnitte unterteilt wird, wobei das Trennmittel an solchen Stellen angeordnet wird, daß die getrennten Abschnitte Setzungen der umgebenden Erde folgen können, **dadurch gekennzeichnet, daß** das Trennmittel (14;20;21) an solchen Stellen bereitgestellt wird, daß die getrennten Abschnitte (15) frei sind, während des Aushärtens des Auskleidungsmaterials zu schrumpfen, und daß die zwischen den getrennten Abschnitten gebildeten Spalte (16) mit einem Dichtmittel (18) ausgefüllt werden.
2. Verfahren nach Anspruch 1, wobei das Trennmittel (14;20;21) geschwächte Bereiche umfaßt, die an vorher bestimmten Stellen in der Tunnelauskleidung angeordnet sind, so daß die Risse in der Tunnelauskleidung, die als Folge des Schrumpfens des aushärtenden Auskleidungsmaterials oder nach Setzungen der umgebenden Erde auftreten, sich nur in den geschwächten Bereichen bilden.
3. Verfahren nach Anspruch 1, wobei das Trennmittel separate Trennelemente (19) umfaßt, die an vorher bestimmten Stellen in die Tunnelauskleidung eingeführt sind, wobei sich die Trennelemente über einen Teil oder im wesentlichen die gesamte radiale Dicke der Tunnelauskleidung (3) erstrecken.
4. Verfahren nach Anspruch 3, wobei die Trennelemente (19) das Dichtmittel zwischen den Abschnitten der Tunnelauskleidung umfassen.
5. Verfahren nach Anspruch 3, wobei die Trennelemente in der Richtung der Bewegungen der benachbarten Abschnitte der Tunnelauskleidung als

Feder wirken.

6. Verfahren nach Anspruch 3, wobei das Trennmittel ein aktives Kompressionsmittel umfaßt.
7. Verfahren nach einem der Ansprüche 1 bis 6, wobei sich das Trennmittel (14) in Umfangsrichtung der Tunnelauskleidung erstreckt.
8. Verfahren nach einem der Ansprüche 1 bis 6, wobei sich das Trennmittel in Längsrichtung der Tunnelauskleidung erstreckt.
9. Verfahren nach einem der Ansprüche 1 bis 6, wobei sich das Trennmittel (21) spiralförmig entlang der Tunnelauskleidung erstreckt.

Revendications

1. Procédé de construction d'un tunnel à revêtement (1) dans la terre comprenant les étapes de creusement d'un tunnel dans la terre au moyen d'une machine excavatrice se déplaçant vers l'avant (4), mise en place d'une structure de support (6) derrière la machine excavatrice après qu'une partie du tunnel a été creusée, de sorte qu'un interstice en forme d'anneau (8) est formé entre la structure de support et la terre environnante, fourniture d'un moyen d'étanchéité (9) pour rendre étanche l'interstice en anneau vers la machine excavatrice, remplissage de l'interstice en anneau derrière le moyen d'étanchéité en y injectant un matériau de revêtement liquide, tel que du béton liquide, et laisser le matériau de revêtement se solidifier et prendre, formant ainsi un revêtement de tunnel (3), des moyens de séparation (14, 20, 21) étant prévus dans le revêtement de tunnel avant prise du matériau de revêtement, de sorte que le revêtement de tunnel (3) est divisé en sections séparées, les moyens de séparation étant situés en des endroits tels que les sections séparées sont libres de suivre des affaissements de la terre environnante, **caractérisé par le fait que** les moyens de séparation (14, 20, 21) sont installés en des endroits tels que les sections séparées (15) sont libres de rétrécir pendant la prise du matériau de revêtement et que les interstices (16) formés entre les sections séparées sont remplis par un matériau d'étanchéité (18).
2. Procédé selon la revendication 1, dans lequel les moyens de séparation (14, 20, 21) comportent des zones affaiblies situées en des endroits prédéterminés dans le revêtement de tunnel, de telle sorte que des fissures dans le revêtement de tunnel résultant du rétrécissement du matériau de revêtement en cours de prise ou suite à des affaissements de la terre environnante ne se produiront que dans

les zones affaiblies.

3. Procédé selon la revendication 1, dans lequel les moyens de séparation comprennent des éléments de séparation distincts (19) insérés en des endroits prédéterminés dans le revêtement de tunnel, les éléments de séparation s'étendant sur une partie de ou sensiblement sur toute l'épaisseur radiale du revêtement de tunnel (3). 5
4. Procédé selon la revendication 3, dans lequel les éléments de séparation (19) comprennent les éléments d'étanchéité entre les sections du revêtement de tunnel. 10
5. Procédé selon la revendication 3, dans lequel les éléments de séparation ont un effet de ressort dans la direction des mouvements des sections adjacentes du revêtement de tunnel. 15
6. Procédé selon la revendication 3, dans lequel les moyens de séparation comprennent des moyens de compression actifs. 20
7. Procédé selon l'une quelconque des revendications 1 à 6, dans lequel les moyens de séparation (14) s'étendent en direction circonférentielle du revêtement de tunnel. 25
8. Procédé selon l'une quelconque des revendications 1 à 6, dans lequel les moyens de séparation (20) s'étendent en direction longitudinale du revêtement de tunnel. 30
9. Procédé selon l'une quelconque des revendications 1 à 6, dans lequel les moyens de séparation (21) s'étendent de façon hélicoïdale le long du revêtement de tunnel. 35

40

45

50

55

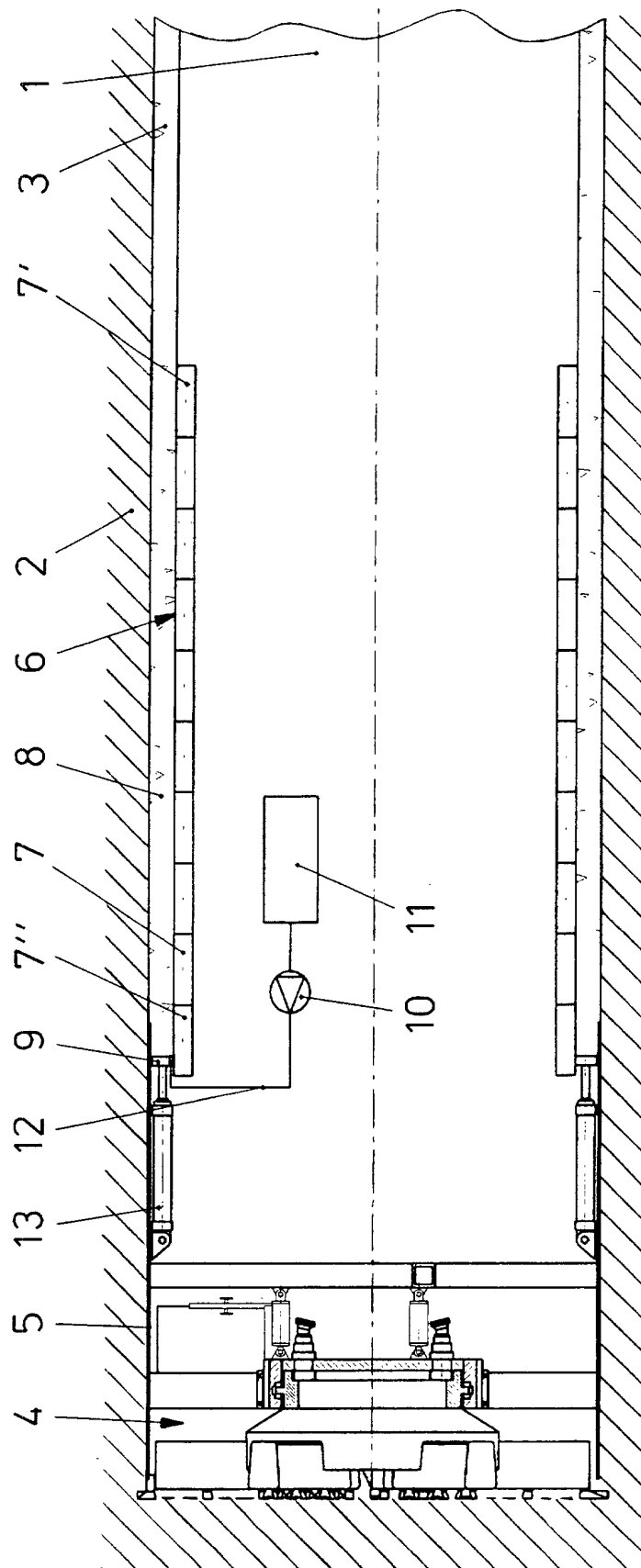


Fig. 1

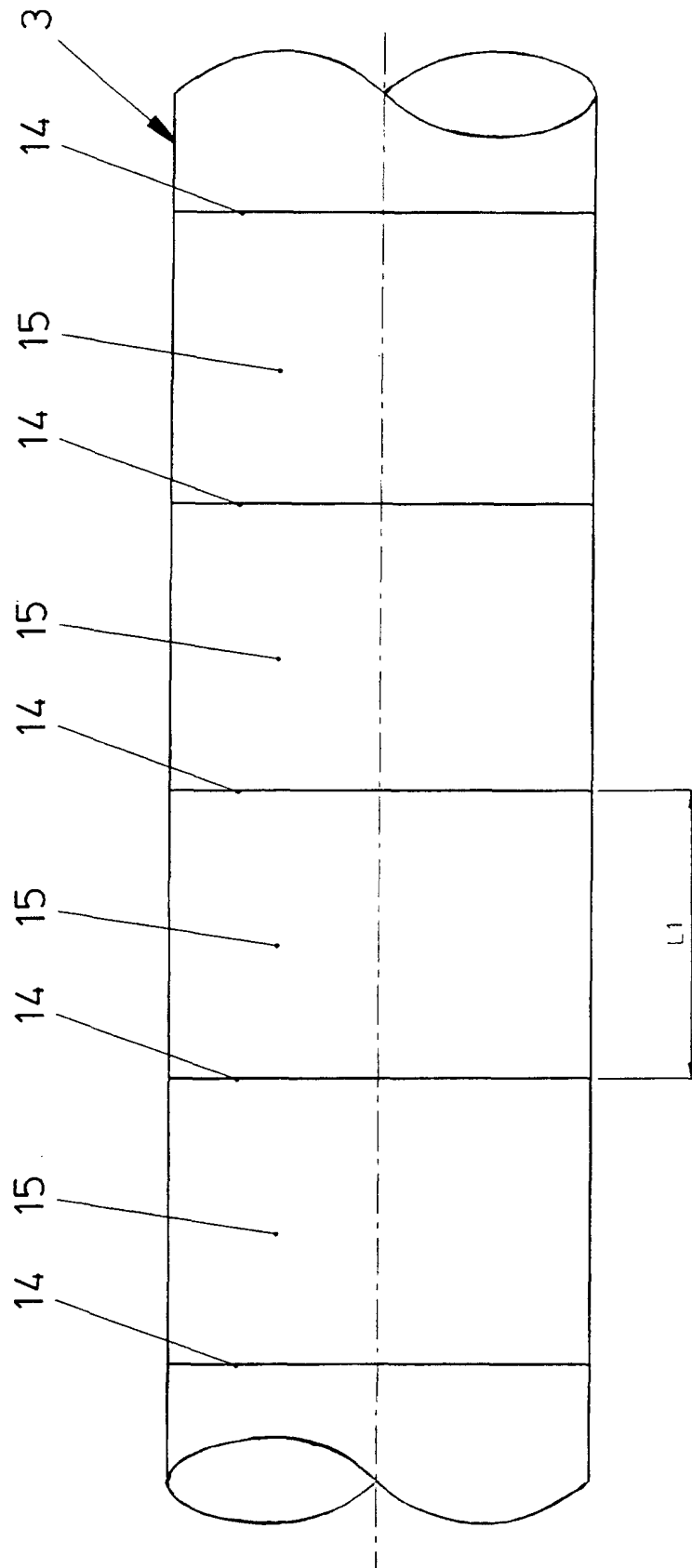


Fig. 2

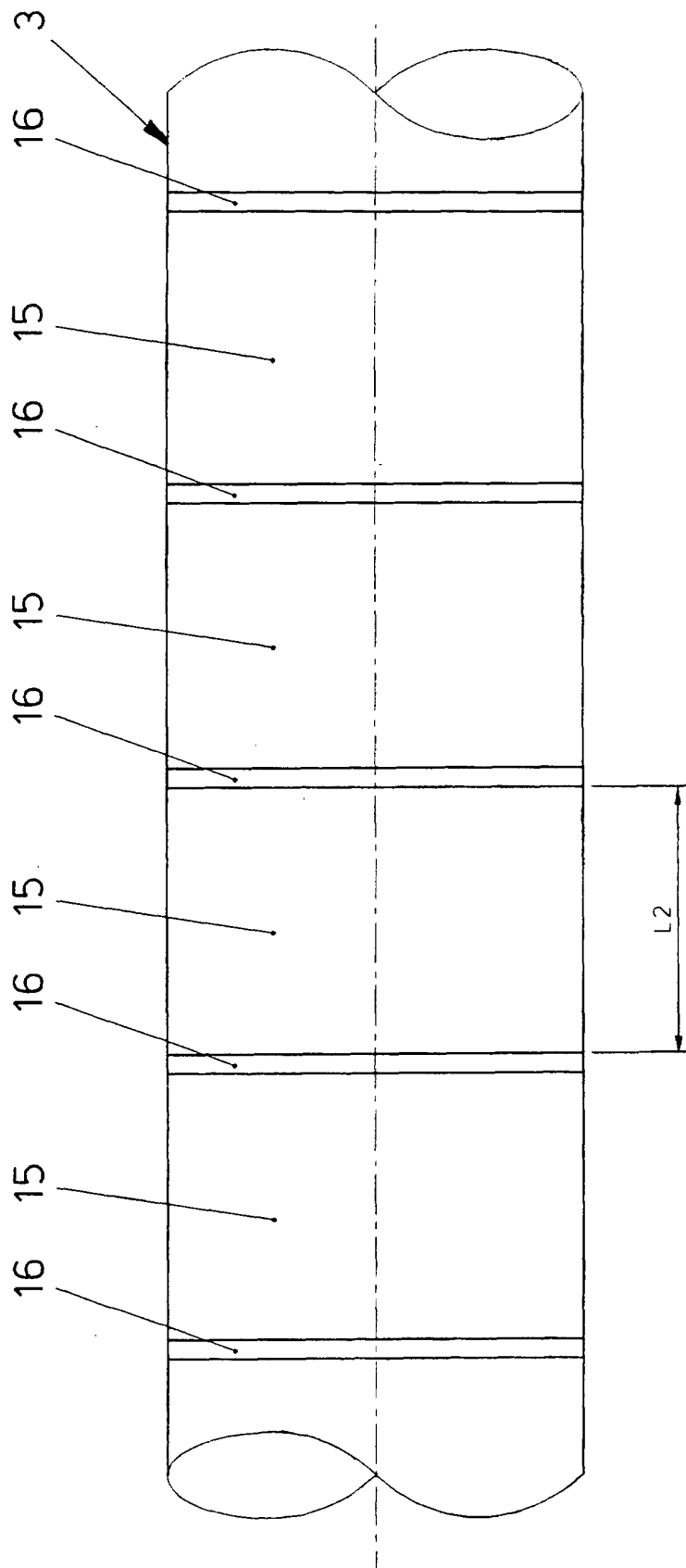


Fig. 3

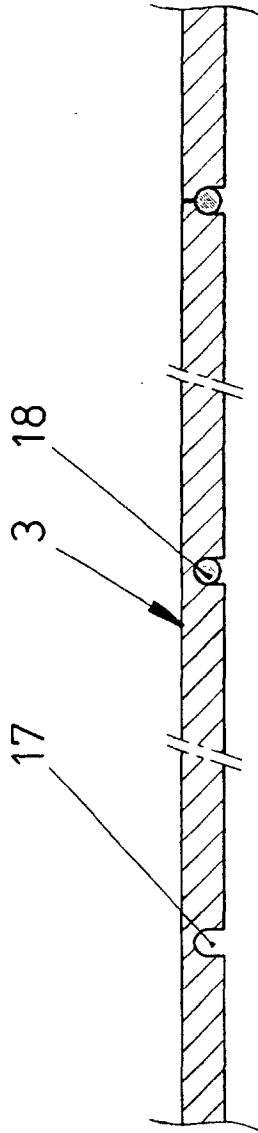


Fig. 4

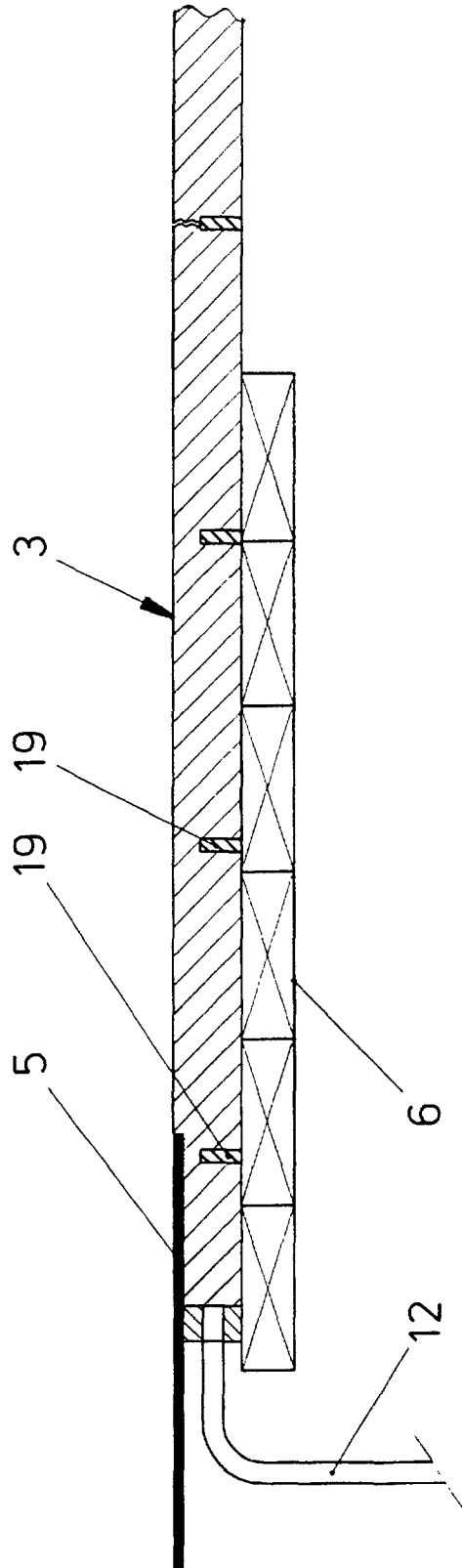


Fig. 5

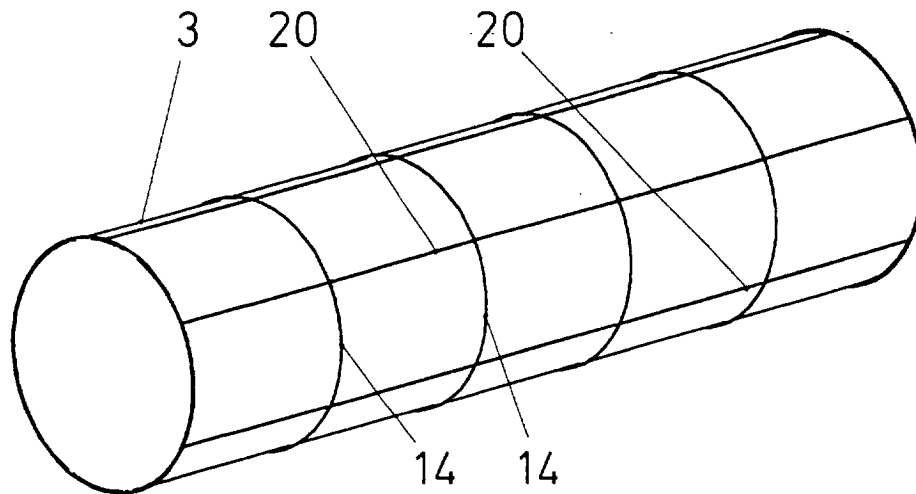


Fig. 6

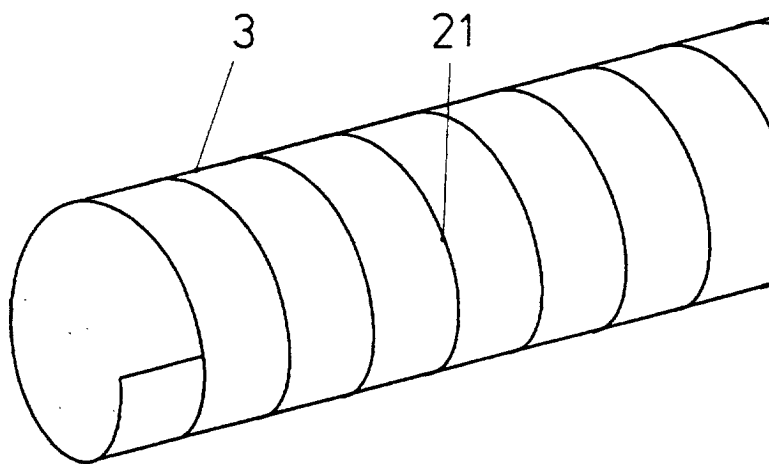


Fig. 7