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

(57) The invention provides a method of building a tunnel comprising an arched structure (1). The method includes the step of driving elongate beams (2) substantially horizontally into the ground in a side-by-side relationship so as to create an arch-shaped structure of

beams. The beams (2) are placed side by side in a watertight manner, and preferably a seal (13; 15) is inserted together with the beams. The ground below the arch-shaped structure is excavated and a floor (6) is provided to define the bottom of the tunnel. The floor may be founded. The invention also includes such tunnel.

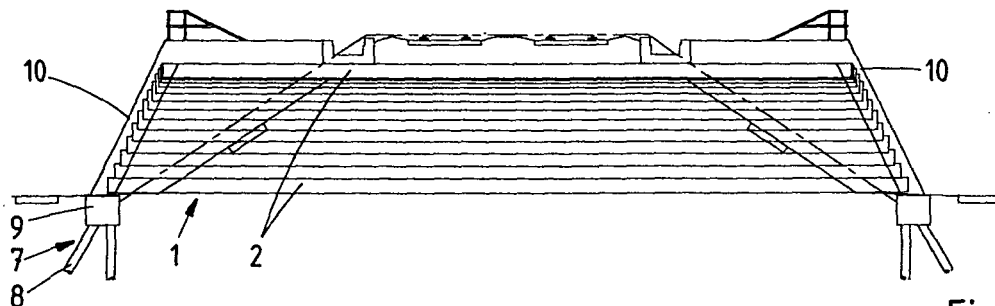


Fig.1

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Description

[0001] The invention relates to a method of building a tunnel comprising an arch-shaped structure as well as to such tunnel.

[0002] A particular application of the invention is to build the tunnel or underpass without causing surface disruption. One example thereof is to build a bicycle underpass below an existing rail track or highway without stopping the use and operation thereof.

[0003] A problem with conventional tunnelling techniques is that for safety reasons a depth of soil of approximately 2 to 3 times the diameter of the tunnel to be excavated is required above said tunnel. This makes conventional techniques impractical. Therefore a number of new methods have been developed. One example thereof is disclosed in US 6,406,220 B1 relating to an arched support structure. According to the disclosed method of building such structure, a series of supporting units is positioned in the soil and during excavating, arched sections are pushed one after another into the excavated area thereby sliding in a track formed in the supporting units.

[0004] It is an object of the present invention to provide a novel method of building a tunnel.

[0005] For this purpose the invention provides a method according to claim 1.

[0006] The method according to the invention is quite simple and may be used to build both short tunnels and longer tunnels in which a plurality of beams is driven into the ground aligned with each up to a desired length. The arch-shaped structure is formed by driving the elongate beams into the ground in a side-by-side relationship and during or after the creation of the arch-shaped structure, the soil below the arch is excavated in order to form the tunnel opening. If the beams are positioned with respect to each other such that a watertight seal is formed between them, there is no necessity to finish the beams on the inner side of the tunnel but the arch can be used right away. This makes the method according to the invention very simple.

[0007] The floor and the foundation can be provided in different ways, depending on the underlying soil and the structure under which the tunnel should be made. Preferably, the elongate beams are driven into the ground while the ground is removed in front of the beams, for example by means of an auger which can be used if the beams are hollow. In that case the auger is inserted through the lumen in the beams and is moved with each beam in order to remove the soil in front of the beam and discharge it through the lumen in the beam. In this manner, the beam is inserted into the ground by a combination of pressing or jacking and drilling. Due to the small cross section of the building elements (i.e. beams) and due to the manner of driving in the building elements, the soil disruption is kept to a minimum.

[0008] The invention also includes a tunnel comprising a plurality of elongate beams positioned side by side in

a watertight manner to create an arch-shaped structure forming the roof of the tunnel, a foundation connected to the arch-shaped structure and a floor. Such tunnel is simple in structure and is easy to build into the ground. The soil and the structures above the tunnel to be excavated are not disrupted so that for example a road above the tunnel can remain in operation during building of the tunnel. If the subsoil is such that no foundation is required, the floor and arch-shaped structure can be supported directly on the subsoil.

[0009] Further details and advantages of the invention will become apparent from the following description with reference to the drawings showing embodiments of the present invention.

[0010] Figs. 1, 3 and 5 are longitudinal sectional views of three different embodiments of a tunnel according to the invention.

[0011] Figs. 2, 4 and 6 are front views of the tunnel embodiments of Figs. 1, 3 and 5.

[0012] Fig. 7 is an enlarged scale front view of an elongate beam for forming the arch-shaped structure in the tunnel according to Figs. 1-6.

[0013] Figs. 8-10 show, on an even larger scale, three embodiments of possible seals between two adjacent beams in the arch-shaped structure.

[0014] Figs. 11 and 12 illustrate two stages in the operation of driving the elongate beams of the arch-shaped structure into the ground.

[0015] Figs. 13 and 14 illustrate in a front view a manner of forming the arch-shaped structure by means of the elongate beams.

[0016] Figs. 15 - 19 illustrate several stages in providing a floor and foundation in the embodiment of the tunnel according to Figs. 3 and 4.

[0017] Fig. 20 is a sectional view according to the line XX-XX in Fig. 19.

[0018] The drawings and in first instance Figs. 1 - 6 show several embodiments of a tunnel or underpass. In the embodiments shown, the tunnel is used to underpass a traffic road or railroad which is built on a bank, so that the tunnel to be excavated is made at ground level. It should be understood, however, that the tunnel and the methods of building one could also be used underground.

[0019] In all three embodiments, the tunnel includes as main part an arch-shaped structure 1 which is formed of elongate beams 2. These beams 2 are of a substantially rectangular shape, but include an arc shape such that the arch will be formed automatically if the beams 2 are in abutting relationship. To position the beams 2 with respect to each other, they are provided with a tong-and-groove system, wherein one side of each beam is provided with a tongue 3, whereas the opposite side is provided with a groove 4 in which the tongue 3 of the next beam 2 fits. The other two sides of the beam 2 are slightly curved, so that when the beams 2 have been fitted to each other there is formed a smooth surface on the inner side of the arch-shaped structure 1. The beams 2 are hollow and have a lumen 5 extending in longitudinal di-

rection through the whole length of each beam 2. The function and advantages thereof will be described later on.

[0020] The tunnel may further include a floor 6 and a foundation 7. In the embodiments of Figs. 1 and 2, the foundation 7 is positioned at the ends of the tunnel and in this case laterally and longitudinally outside the arch-shaped structure 1. The foundation 7 comprises in this embodiment foundation piles 8 and supporting heads 9 resting on the piles 8. In the embodiment shown, the transverse supporting heads 9 support the ends of an arch-shaped end beam 10 created around the ends of the elongate beams 2 and being fixed thereto. This end beams 10 may also support or be connected to a further superstructure 11 provided on the bank B. In this embodiment, there may be provided pre-tensioning elements, such as cables or rods through the lumen 5 in the beams 2, which are stretched and fixed outside the beams 2, for example to the end beams 10. These pre-tensioning elements will increase the strength of the arch-shaped structure 1.

[0021] In the embodiment of Figs. 3 and 4, the floor 6 is part of the foundation and for this purpose, the floor 6 is fixed on its lateral sides 2 at least to the lower beams 2 of the arch-shaped structure 1 and is supported on foundation piles 12. The floor 6 may be made of prefabricated elements or may be cast in situ. The method of building this embodiment of the tunnel according to the invention will be explained later on with reference to Figs. 15 - 19.

[0022] Figs. 5 and 6 show an embodiment of the tunnel according to the invention, in which the underground or subsoil functions as the foundation of the tunnel. Such embodiment is possible for example if the underground consists of non-settling material, such as rock or sand. In these embodiments, the floor 6 and the arch-shaped structure 1 are formed directly on the underground or subsoil.

[0023] Figs. 7 - 10 show the cross-sectional shape of the elongate beams 2 in more detail. If the arch shape of the structure 1 has a constant curvature, all beams 2 may have the same cross section, but in principle it is possible to create an arch which has different curvatures along its cross-section and in that case beams 2 with different cross sections will be used along the length of the arch.

[0024] Figs. 8 - 10 show three embodiments of a seal between adjacent beams 2 in order to obtain water tightness of the arch-shaped structure 1. In that case, no finishing or sealing layers are necessary on the inside or outside of the arch-shaped structure.

[0025] In the embodiment of Fig. 8, a porous tube or hose 13, for example made of coconut fibre material, is provided between the tongue 3 and groove 4 of the adjacent beams 2 and preferably this tube or hose 13 is accommodated partly in a small notch 14 in the tongue 3 of the beams 2. Preferably, the tube 13 is introduced simultaneously with one of the adjacent beams 2.

After creation of the arch-shaped structure 1, a sealing fluid, such as grout or the like, is injected into the tube 13 and this fluid fills the tube 13 but will also leave the tube through the pores in order to fill the space between the adjacent beams 2. In this way there is created a watertight seal between the beams 2 in the arch-shaped structure 1.

[0026] Fig. 9 shows the second embodiment wherein a solid rubber seal 15 is positioned under tension between the tongue 3 and groove 4 of adjacent beams 2 in order to create a watertight seal.

[0027] Fig. 10 shows a third embodiment which is a combination of the embodiments of Figs. 8 and 9. In this third embodiment a rubber seal 15 is provided in a notch 14 in the tongue 3 of one of the beams 2 and this rubber seal 15 may be filled in order to either create pressure from the inside to close off the space between the adjacent beams 2 or to be enable the rubber seal to accommodate movements and forces between the adjacent beams 2.

[0028] A method of building a tunnel including an arch-shaped structure 1 will now be elucidated, in first instance with reference to Figs. 11 - 14.

[0029] The arch-shaped structure 1 is created by subsequently driving a plurality of elongate beams 2 substantially horizontally into the ground, in this case into the ground forming a bank B, in a side-by-side relationship. In order to drive each beam 2 into the ground, a driving apparatus 16 is used which uses a combination of drilling and pressing or jacking to drive the beams 2 into the ground. In order to guide the beams 2 through the ground, a pilot rod 17 is driven into the ground by means of the driving apparatus 16. Said pilot rod 17 has a small diameter and has a pointed tip in order to cut through the ground easily. This piloting operation is illustrated in Fig. 11.

[0030] Fig. 12 shows the next step in the driving operation and in this step, the beams 2 are driven into the ground guided around the pilot rod 17. In order to facilitate the insertion of the elongate beams 2 into the ground use is made of a ground drill or auger 18 which is hollow so as to be guided around the pilot rod 17 and which is introduced in the ground together with the beam. For this purpose, the auger 18 is inserted into the beam 2 through the lumen 5 therein and this auger 18 projects slightly from the driving end of the beam 2 so as to remove the ground in front of the beam 2 and to discharge this ground or soil through the lumen 5 to a position behind the beam 2. As a result, the beam 2 is introduced into the ground by a combination of drilling and pressing as this beam 2 is forced into the ground by pressure exerted by the driving apparatus 16. As is shown in Fig. 12, a plurality of beams 2 are driven into the ground in alignment with each other such that the combined length of the aligned beams 2 corresponds with the desired length of the arch-shaped structure. Different lengths of the beams 2 may be used or the end beams 2 can be cut off at the desired length if the length of the arch-shaped structure 1 varies

along the arch.

[0031] As is illustrated in Figs. 13 and 14, the creation of the arch-shaped structure 1 is started with a centre beam 2' which does not have a tongue 3 and groove 4 at opposite sides, but has a groove 4 on opposite sides. In this way, the cross section of the tunnel is symmetrical with the tongues 3 of the beams 2 being directed to the centre of the arch on both sides of the centre beam 2'. The halves of the arch-shaped structure 1 are created one after the other. Of course, other ways of creating the arch are conceivable.

[0032] Figs. 15 - 19 illustrate a method of excavating the tunnel and providing the floor and foundation of the tunnel, in particular in the embodiments according to Figs. 3 and 4.

[0033] Fig. 15 shows the situation after the arch-shaped structure 1 has been created. Then the soil within the arch-shaped structure 1 is removed in a segment S on one end of the arch-shaped structure 1.

[0034] In fig. 16, a floor 6 is created in this excavated segment S and in case the floor 6 is founded, foundation piles 12 are first driven into the soil before the floor 6 is provided thereon. If the floor 6 is finished in this first segment S, the next segment S is excavated as is illustrated in Fig. 17. This next segment S is neighbouring the first segment S. As is illustrated in Fig. 18, the floor 6 and the foundation 7 are then provided in this second segment S. This operation is continued until all of the soil within the arch-shaped structure 1 has been excavated and the floor 7 has been provided at the bottom of this excavated tunnel. If the tunnel is of greater length or if loads on the arch-shaped structure 1 are relatively high, it is possible to form one or more cambered trusses 19 at one or more positions between the ends of the arch-shaped structure 1 to improve the strength of this structure. This truss 19 is shown in Figs. 19 and 20.

[0035] It is clear from the foregoing description that the invention provides a method with which a tunnel can be built in a simple and quick manner without disturbing the soil above it.

[0036] The invention is not limited to the embodiments described above and shown in the drawings which can be varied in different manners within the scope of the appended claims. For example, the cross-sectional shape of the arch may be varied, and more resemble a rounded rectangle. In such arrangement, the vertical support for beams by the adjacent beam will be less in the centre of the tunnel, so it is desirable then to provide a supporting arch. Preferably, the beams are driven into the ground subsequently, but it is also conceivable that more than one beam is inserted at a time.

Claims

1. A method of building a tunnel comprising an arched structure (1), including, in a desired order, the steps of:

driving elongate beams (2) substantially horizontally into the ground in a side-by-side relationship so as to create an arch-shaped structure of beams,
excavating the ground below the arch-shaped structure, and
providing a floor (6) to define the bottom of the tunnel.

2. The method of claim 1, wherein the elongate beams (2) are driven into the ground while the ground is removed in front of the beams.

3. The method of claim 2, wherein the elongate beams (2) are hollow, and a ground drill (18) is inserted through the hollow in the beams and is moved with the beams in order to remove the ground in front of the beams and discharge it through the hollow beams.

4. The method of claim 1 for building a long tunnel, wherein a plurality of beams (2) is driven into the ground aligned with each other.

5. The method of any one of the preceding claims, including the step of creating a foundation (7) and connecting it to the arch-shaped structure (1).

6. The method of claim 5, wherein the foundation (7) is provided under the floor (6) and wherein, preferably, the soil under the arch-shaped structure (1) is excavated in longitudinal direction segment (S) by segment (S), and the foundation and floor are built in one of the segments and fixed to the arched-shaped structure before the next segment is excavated, and wherein preferably one or more trusses are formed at one or more positions between the ends of the arch-shaped structure (1).

7. The method of any of the preceding claims, wherein the foundation (7) is built at the ends of the arch-shaped structure below the lower beams (2), and wherein an end beam (10) may be added supporting a structure (11) on top of the tunnel, while pretension cables may be stretched through the hollow beams and fixed to the end beams (10).

8. The method of any of the preceding claims, wherein the beams (2) are placed side by side in a watertight manner, preferably a seal (13; 15) is inserted together with the beams, for example a porous tube (13) is accommodated in a hollow space (14) between two adjacent beams and a sealing substance, such as grout, is pressed into the porous tube after installation of the beams.

9. A tunnel comprising a plurality of elongate beams (2) positioned side by side in a watertight manner to

create an arch-shaped structure (1) forming the roof of the tunnel, a foundation (7), if required, connected to the arch shaped structure, and a floor (6).

- 10.** The tunnel of claim 9, comprising a seal (13; 15) between the adjacent beams (2), the seal including at least one of a rubber seal (15), a sealant filled rubber seal (15) and a porous tube (13) filled with a sealant such as grout. 5
- 10
- 11.** The tunnel of claim 9 or 10, wherein the beams (2) are hollow, and may have pretension elements extending through the hollows.
- 12.** The tunnel of any of claims 9 - 11, wherein the foundation (7) is a (pile) foundation (12) built under the floor (6) of the tunnel which is fixed to the arch-shaped structure (1), or a (pile) foundation (8) built under the ends of the arch-shaped structure (1) and supporting the lower beams (2). 15
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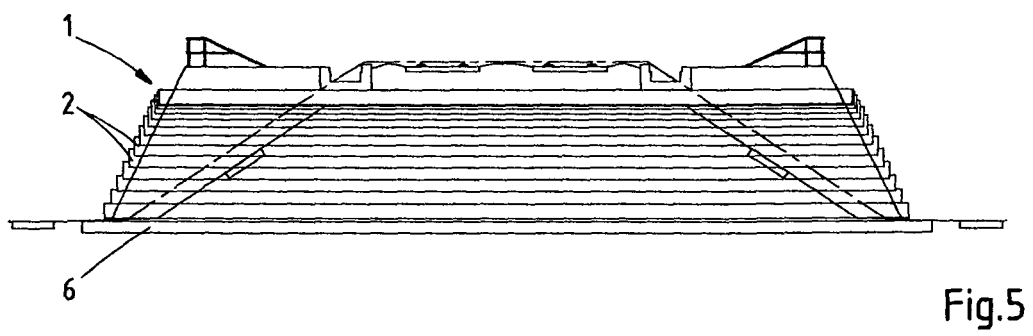
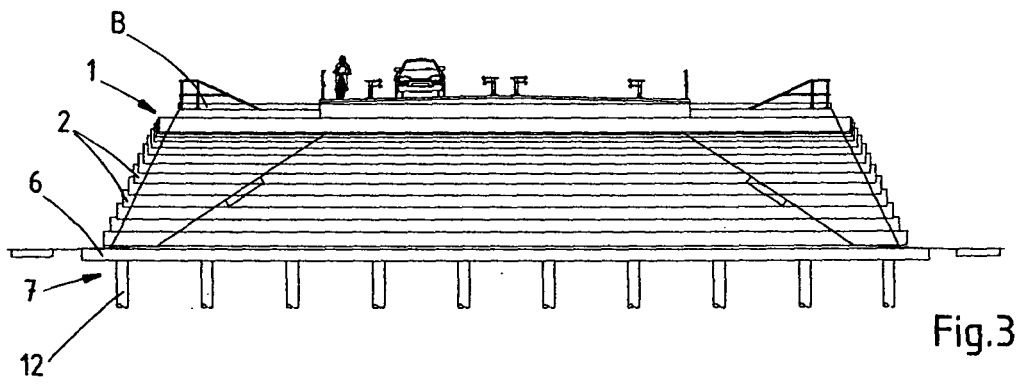
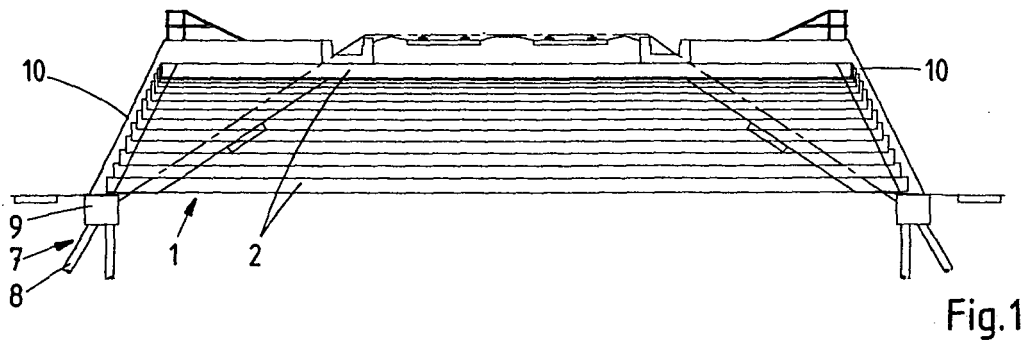
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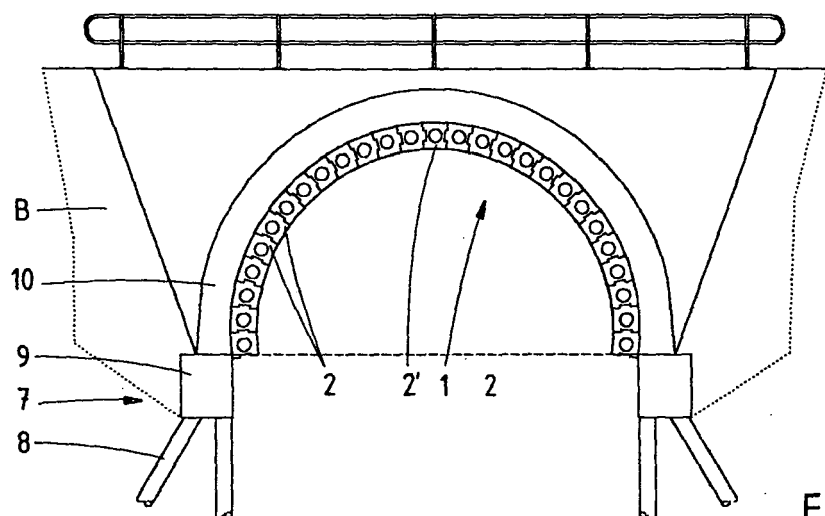


Fig.2

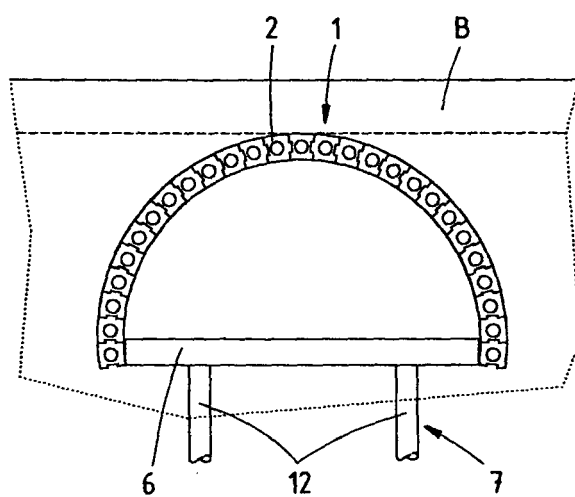


Fig.4

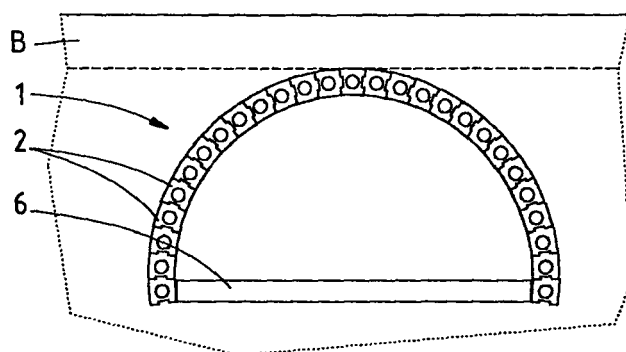


Fig.6

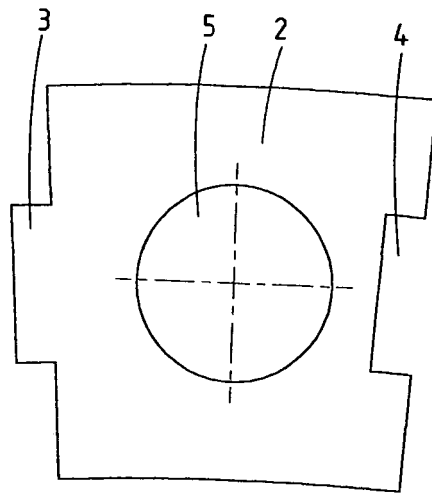


Fig. 7

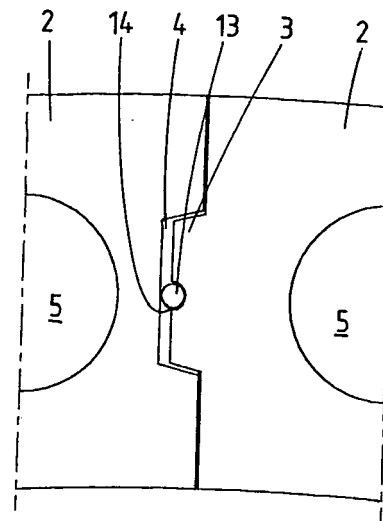


Fig. 8

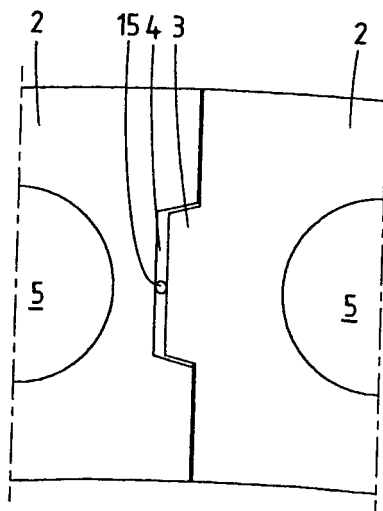


Fig. 9

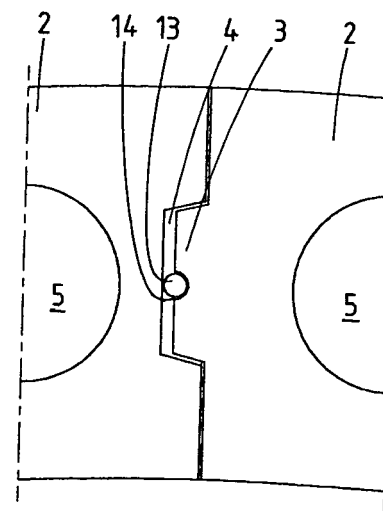


Fig. 10

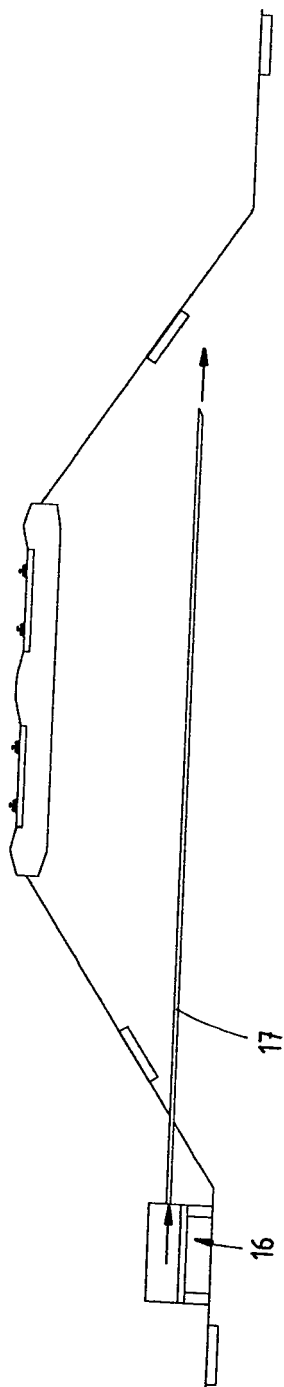


Fig. 11

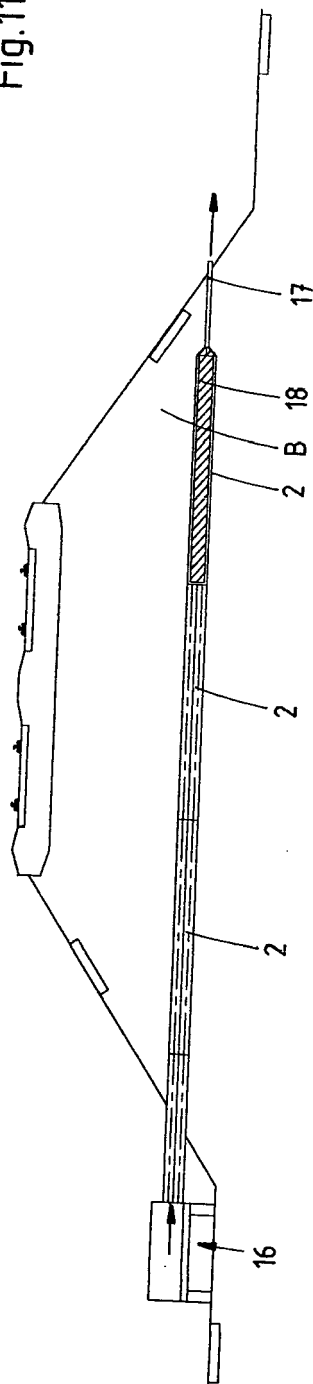


Fig. 12

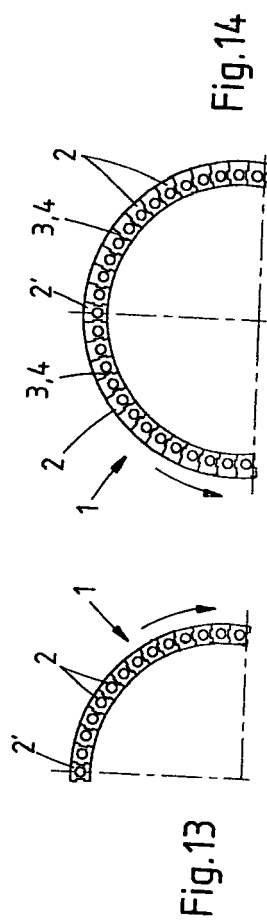


Fig. 13

Fig. 14

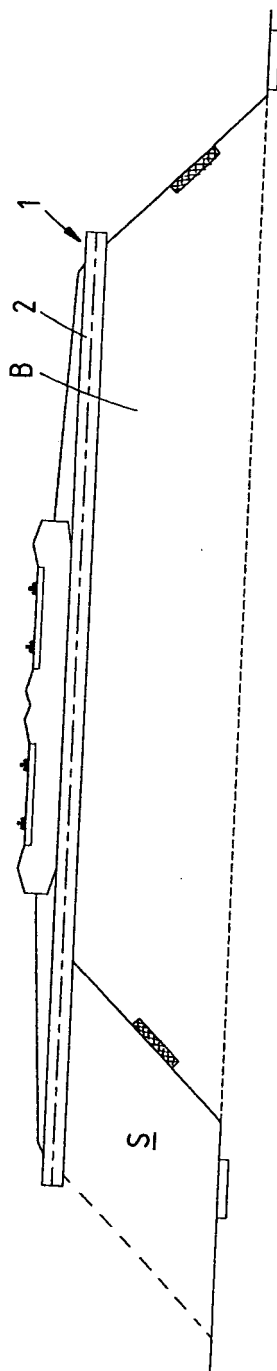


Fig. 15

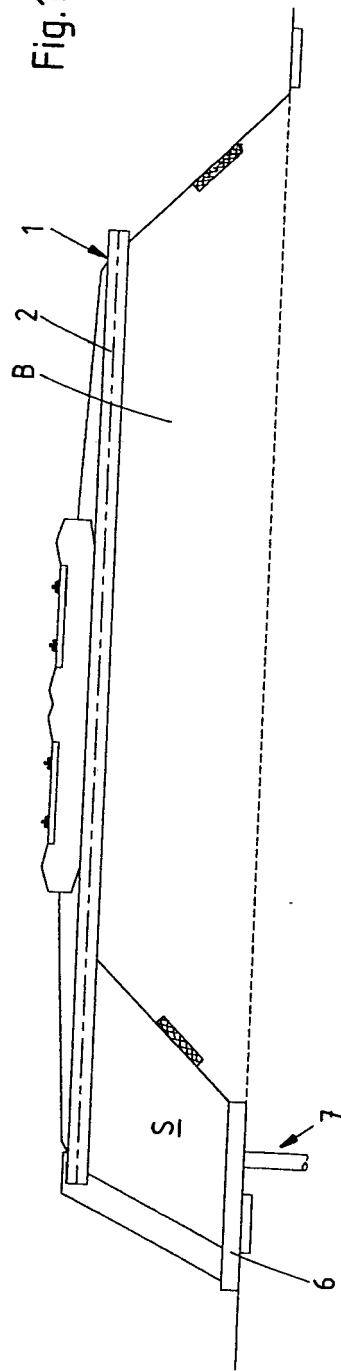


Fig. 16

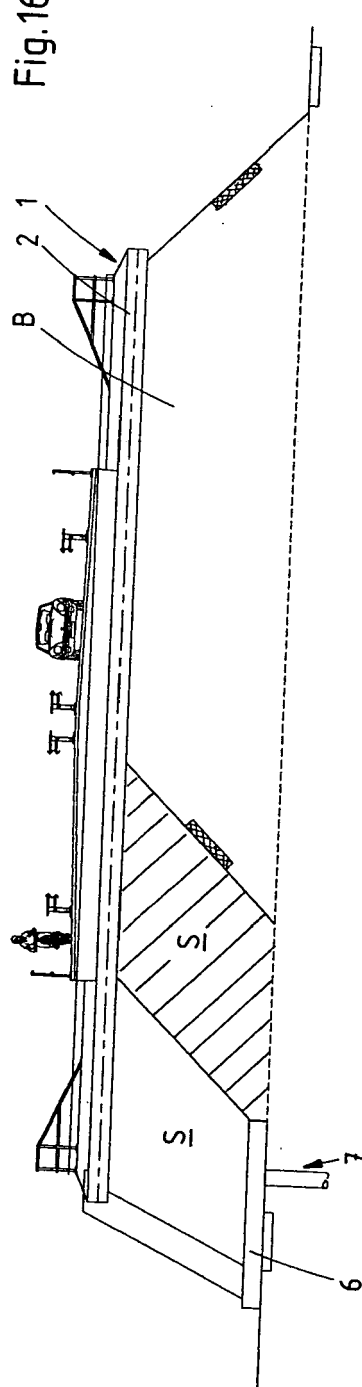
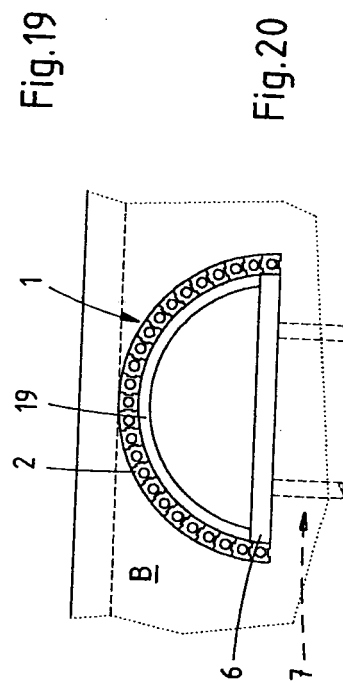
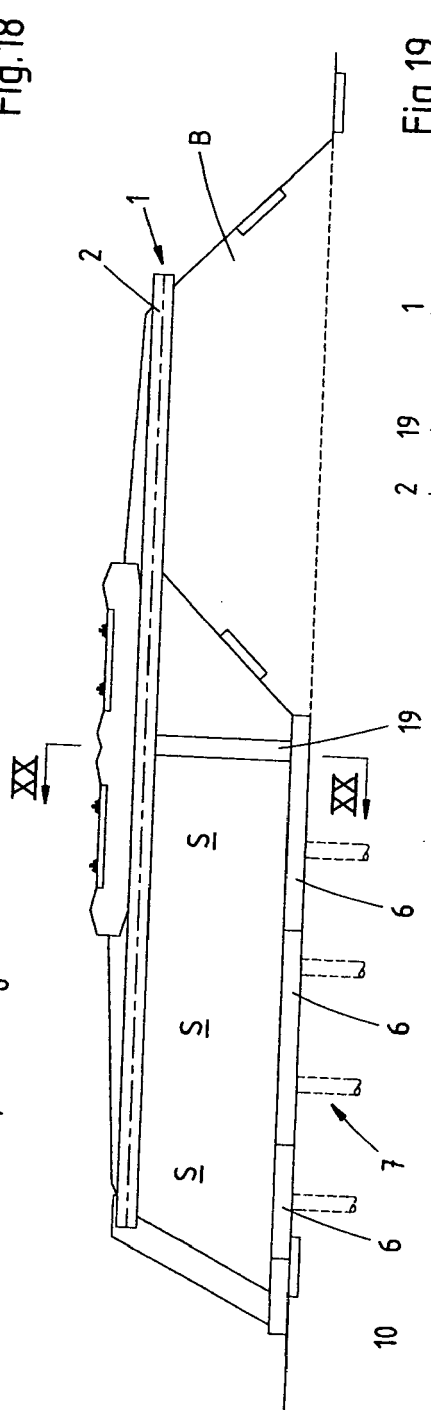
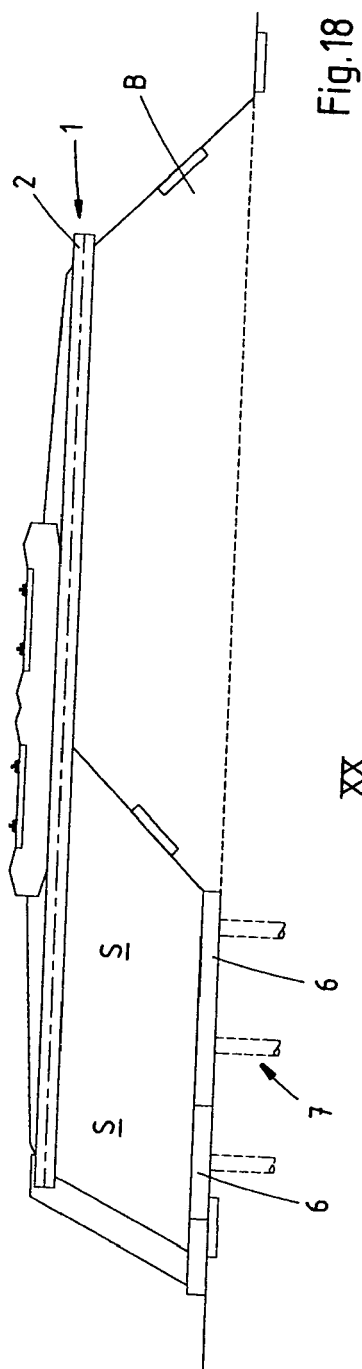


Fig. 17





European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 04 10 6796

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 4 139 320 A (UENO ET AL) 13 February 1979 (1979-02-13) * column 3, lines 22-47 *	1-4	E21D9/00 E21B7/20 E21D11/38
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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 21 July 2005	Examiner Garrido Garcia, M
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 04 10 6796

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The present search report has been drawn up for all claims				
Place of search The Hague		Date of completion of the search 21 July 2005	Examiner Garrido Garcia, M	
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document				

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EPO FORM 1503 03.82 (P04C01)



European Patent
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Application Number
EP 04 10 6796

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

- ☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):
- ☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

- ☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.
- ☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.
- ☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:
- ☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:



European Patent
Office

**LACK OF UNITY OF INVENTION
SHEET B**

Application Number
EP 04 10 6796

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-7,9,11,12

Method of building a tunnel

2. claims: 8,10

Seal for tunnel lining elements

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 04 10 6796

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

21-07-2005

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