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- **Valagussa, Carlo**
20145 Milano (IT)
- **Zanelotti, Letizia**
20826 Secugnago (IT)
- **Fava, Adriano Ruggero**
20126 Milano (IT)

(71) Applicant: **Alpina S.p.A.**
20136 Milano (IT)

(74) Representative: **Gervasi, Gemma et al**
Notarbartolo & Gervasi S.p.A.
Corso di Porta Vittoria, 9
20122 Milano (IT)

(72) Inventors:
• **Peri, Guido**
20145 Milano (IT)

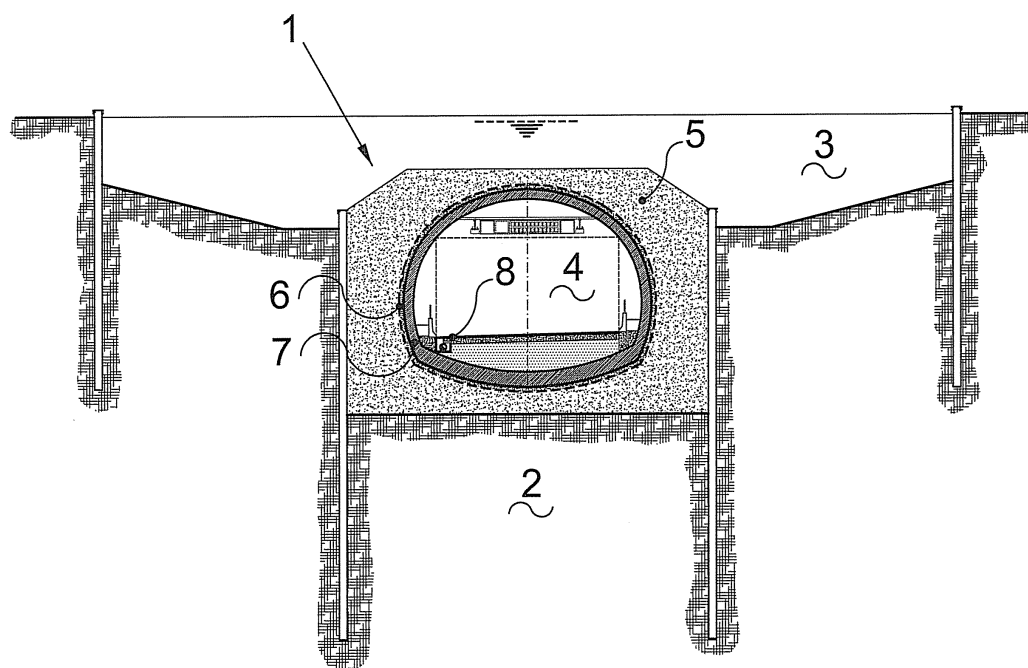
(54) **Method for constructing an immersed tunnel and tunnel obtained by said method**

(57) An immersed tunnel of the type comprising a formwork structure (6), an underwater concrete casting (5) which externally surrounds said structure (6) and internal finishes (8), in which the mentioned formwork structure (6) consists of a plurality of open-ended segments (9, 12) allowing the entrance of water present at

the laying site of said tunnel.

In relation to the above-described known art, the tunnel of the invention offers the advantage of being able to be laid in an immersed state, i.e. directly in its place of installation. In this manner, all the traditional problems related to the dredging of the tunnel laying site are overcome.

Figure 2



Description

[0001] The present invention relates to a method for constructing an immersed tunnel. The invention further extends to the immersed tunnel constructed by this method.

[0002] The field of the invention is that of road and railway tunnels, for traversing and the like, constructed immersed in water or in water-bearing ground, such as loose ground entirely permeated by groundwater or tunnels crossing under sea channels, rivers or expanses of water in general.

[0003] In constructions of this type, it is known to lay the tunnel either after dredging the place of installation of the same (when this is possible), or by making the preparation of the tunnel in a dry environment, i.e. outside the final site, precede the laying of the same with subsequent installation of the artefact.

[0004] In the first solution, the main drawback is represented by the need to dry out the laying site, i.e. an operation which, in addition to not always being feasible, implies major works in relation to the containment of both the ground and the water.

[0005] On the other hand, the installation of a prefabricated reinforced concrete tunnel has disadvantages related both to the transferring of the construction to its site of use and to the need to install the various tunnel segments in immersed position, appropriately and reciprocally centred and constantly maintained in sealed closed state. To these, there is added the non-negligible problem of installing in its site a heavy, very large artefact which tends by its own nature to float.

[0006] It is the main object of the present invention to provide an immersed tunnel which, unlike the above-described known structures, does not require the preventive dredging of the installation site of the same and in which the immersion in water of the tunnel segments does not imply any step of floating.

[0007] The invention has the further purpose of providing a tunnel of the aforementioned type in which the preparation of prefabricated segments outside the installation trench of the artefact is not provided.

[0008] These and other objects are achieved by the method and the tunnel of claims 1 and 13, respectively. Preferred modes of obtaining the immersion result from the remaining claims.

[0009] In relation to the above-described known art, the tunnel of the invention offers the advantage of being able to be laid in an immersed state, i.e. directly in its place of installation. In this manner, all the traditional problems related to the dredging of the tunnel laying site are overcome.

[0010] Compared to the traditional prefabricated segment technology, the invention offers the advantage of not requiring either the transportation of heavy artefacts, which are thus difficult to handle, nor the immersed assembly of prefabricated tunnel segments, nor the preventive preparation of definitive sealing joints between

the various segments.

[0011] These and other objects are achieved by the method and the tunnel of the present invention depicted by way of non-limitative example in the figures of the accompanying drawings, in which:

- figure 1 shows a longitudinal section of an example of immersed tunnel according to the invention;
- figure 2 shows a cross section A-A of the tunnel in figure 1;
- figure 3 shows the initial step of immersing the first segment of the tubular formwork structure of the tunnel in figure 1;
- figure 4 shows the step of laying the segment in figure 3;
- figure 5 shows a side view of the step of immersing the second segment of the tunnel in figure 1;
- figure 6 shows the enlarged detail of the connection section of the segments in figure 5; and
- figure 7 shows a cross section of the step of underwater concrete casting of the tunnel in figure 1.

[0012] The tunnel of the invention is indicated as a whole by numeral 1 in figure 1. It essentially consists of a liner 4 resting on bed 2 of a basin covered by water or by ground water 3. Tunnel 1, once laid, could be even entirely covered by the ground forming the mentioned bed 2, and is in any case incorporated in underwater concrete casting 5 shown in figure 2. Specifically, the latter figure shows tubular formwork structure 6, which consists in a plurality of shaped transversal segments shaped as the crown and the tunnel invert of the internal section of tunnel 1, the mentioned segments being reciprocally connected at corresponding joint and sealing sections 15, 17 (figure 6). Structure 6 is completed with a final internal reinforced concrete lining 7 and with the finishes 8 of the roadway within the tunnel itself.

[0013] The trench, prepared along the route of the tunnel to be constructed, following its future longitudinal profile, is made leaving the water of the channel or river to the crossed or the groundwater in site. The side walls of the trench are supported by means of diaphragm walls, either prefabricated or made directly onsite, also with the construction of natural sloping terraces, supported by vertical elements, providing these are compatible with the temporary occupation constraints of the construction site ground.

[0014] The initial step of laying tunnel 1 in figure 1 provides for the immersion, directly in the water 3 of the basin of installation of the same, of the first open-ended tubular segment 9 forming tubular formwork structure 6 (e.g. having a length of 10-12 m). The operation is preferably performed by means of a crane 10 mounted on an appropriate floating barge (not shown). This segment 9, once immersed, rests on ground bed 2, filling itself with water 3 and maintaining its shape also in virtue of the presence of internal structural contrasts 11. Appropriate supports (e.g. metallic poles regularly driven into the bed

of the trench) ensure the laying linearity and geometric correctness.

[0015] Having thus laid segment 9, the second segment 12 equal to the previous one is arranged by the side in the manner shown in figure 5. During this step, the mentioned segments 9 and 12 are fastened head-to-head, at their shaped section 13, as shown in greater detail in figure 6. As shown in this figure, the first segment 9 of the tunnel provides, at its head or end 14, a groove 15 comprising a lead-in 16 for a corresponding rib 17 provided on head 18 of second segment 12. In this manner, the descent or immersion of this segment 12 (arrows in figures 5 and 6) also allows the desired fastening and dimensional mating with the mentioned first segment 9. Finally, the joint is consolidated by means of a seal 19 of injectable, expanding material (e.g. rubber or acrylic resins), preassembled in the mentioned head 14 of segment 9 and the tightness of which is ensured by the geometric fixity of the mentioned segments 9 and 12, obtained by means of rib 17 and groove 15. The laying of the remaining segments of the tubular formwork structure 6 of the tunnel is completed by proceeding with this procedure.

[0016] Having completed the route of the immersed tunnel, there is thus obtained a tubular structure 6, as long as the entire tunnel segment, which forms a proper formwork on which there is made an underwater concrete casting 5, laterally delimited by the containment walls of the trench, to cover the entire structure 6. Concrete casting 5 provides the structural and hydraulic requirements needed for the subsequent finishing operations of the artefact, while the mentioned structure 6 determines a "negative", "disposable" formwork of the casting, leaving inside the latter a free volume, although still full of water at this step, for the construction of the tunnel.

[0017] From this point onwards, the water contained inside tunnel structure 6 is emptied by means of a pumping operation performed on the tunnel ends. Concrete casting 5, along with tubular structure 6, forms a provisional structure which, once the water is emptied, supports the positive buoyancy and the load of the infill ground.

[0018] The final structural support and water infiltration barrier functions are thus entrusted, during the step of use, to a definitive lining consisting of a reinforced concrete casting 7 performed from within, after removing structural contrasts 11 and by means of the use of a normal tunnel formwork, using tubular steel structure 6 as an external containment wall of the casting itself. Finally, finishes 8 are made within the structure thus obtained.

[0019] Changes may be made to the invention described and illustrated above to make variants which are however comprised in the scope of protection of the following claims.

[0020] Thus, for example, the single segments forming tubular structure 6 could be equipped with the mentioned internal lining 7 even before being immersed in water. The position of rib 17 and seal 19 could be reversed with

respect to that shown in figure 6. Other technical solutions could be in any case adopted to reciprocally seal and fasten the various segments forming the mentioned structure 6.

5 [0021] The installation of tubular structure 6 may further occur by longitudinally sliding the various segments, with gradual immersion of the same joined one to the other. In this manner, structure 6 will continue to elongate as the laying of the mentioned segments progresses, maintaining its "tail" at the natural surface line while its "head" advances towards the valley point of the trench. The sliding of the various segments is obtained at runways made of prefabricated concrete elements, on which the necessary metallic equipment for the sliding of tubular structure 6 is mounted. The latter is further preferably formed by metallic material for railway tunnels, road tunnels and the like; alternatively, it may be formed by resin for containing cables, liquids, and the like.

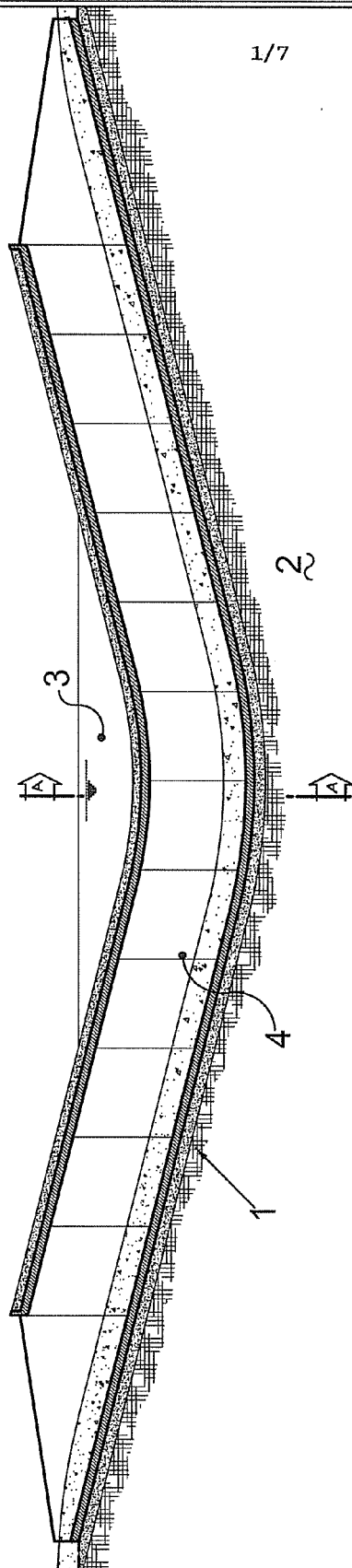
10 [0022] Finally, the invention is not restricted only to the underwater tunnel illustrated in the figures, but may be extended both to even only partially immersed tunnels or tunnels laid in loose ground, and tunnels formed by several formwork structures 6 arranged side by side and embedded in the concrete casting 5 itself (e.g. double barrel tunnels).

Claims

- 30 1. A method for constructing an immersed tunnel, **characterised in that** the entire installation of the tunnel is completely performed in immersed state, i.e. directly in the place of installation of the tunnel itself.
- 35 2. A method according to claim 1, **characterised in that** it provides the formation of a formwork structure (6) of said tunnel, this formation being made by gradual immersion and reciprocal engagement in water of a plurality of open-ended tunnel segments.
- 40 3. A method according to claim 2, **characterised in that** the mentioned structure (6) determines a "negative", "disposal" formwork for the subsequent underwater concrete casting (5), outside and about the formwork itself still full of water.
- 45 4. A method according to claim 3, **characterised in that** it provides the emptying of the water contained within said formwork structure (6) after the mentioned underwater concrete casting (5).
- 50 5. A method according to claim 4, **characterised in that** it further provides the formation of a lining, within the mentioned formwork structure (6) emptied of the water, consisting of a reinforced concrete casting (6) using the structure (6) itself as external containment wall of the casting itself.
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6. A method according to claim 5, **characterised in that** the tunnel finishes (8) are made within said structure (6) thus obtained.
7. A method for the construction of an immersed tunnel, **characterised in that** it provides:
- the formation of a laying site of said tunnel,
 - the construction of a formwork structure (6),
 - the casting (5) of an underwater concrete about the mentioned structure (6), wherein all the mentioned operations are performed in an immersed state, i.e. directly in the place of installation of said tunnel and with the open structure (6) allowing the entrance of water inside.
8. A method according to claim 7, **characterised in that** it contemplates the gradual immersion and the laying of a plurality of open-ended, reciprocally sealed segments forming said formwork structure (6) to complete the entire development of the mentioned formwork structure (6).
9. A method according to claim 8, **characterised in that** it provides the immersion and the laying, from the top, of a formation first segment (9) of said formwork structure (6), the immersion and the laying of a second segment (12) of the same structure (6), with the concurrent fastening and sealed dimensional mating of the mentioned components (9, 12), the operation being continued until the entire development of said formwork structure (6) is completed.
10. A method according to claim 8, **characterised in that** it contemplates the immersion and the laying, by longitudinal sliding, of said segments forming the mentioned formwork structure (6), with gradual immersion of the same joined in sequence one to the other.
11. A method according to claim 8, **characterised in that** it further provides the making of a lining (7) inside said segments, preceded by the emptying of the water (3) from the mentioned formwork structure (6).
12. A method according to claim 8, **characterised in that** the single segments which form said tubular structure (6) are equipped with an internal lining (7) even before being immersed.
13. An immersed tunnel, of the type comprising a formwork structure (6), an underwater concrete casting (5) which externally surrounds said structure (6) and internal finishes (8), **characterised in that** it is constructed with the method according to one or more of the preceding claims.
14. A tunnel according to claim 13, **characterised in that** the mentioned formwork structure (6) consists of a plurality of open-ended segments (9, 12) allowing the entrance of water present in the laying site of said tunnel.
15. A tunnel according to claim 14, **characterised in that** said segments (9, 12) are provided, at their heads (14, 18), with shaped sections (13) suitable for obtaining the fastening and sealed dimensional mating of the segments themselves.
16. A tunnel according to claim 15, **characterised in that** said shaped sections (13) comprise a groove (15) on the mentioned head (14) of said element (9), integrated with a fastening and sliding lead-in (16) with a corresponding rib (17) provided on the head (18) of the contiguous segment (12).
17. A tunnel according to claims 15 or 16, **characterised in that** the shaped section (13) of one of said segments (9, 12) further comprises a seal (19) of the injectable type.
18. A tunnel according to claim 13, **characterised in that** said formwork structure (6) is a metallic material tubular structure for railway tunnels, road tunnels and the like.
19. A tunnel according to claim 13, **characterised in that** said formwork structure (6) is a resin tubular structure for the containment of cables, liquids and the like.
20. A tunnel according to one or more of the preceding claims, **characterised in that** it is a single or double barrel tunnel.

Figure 1



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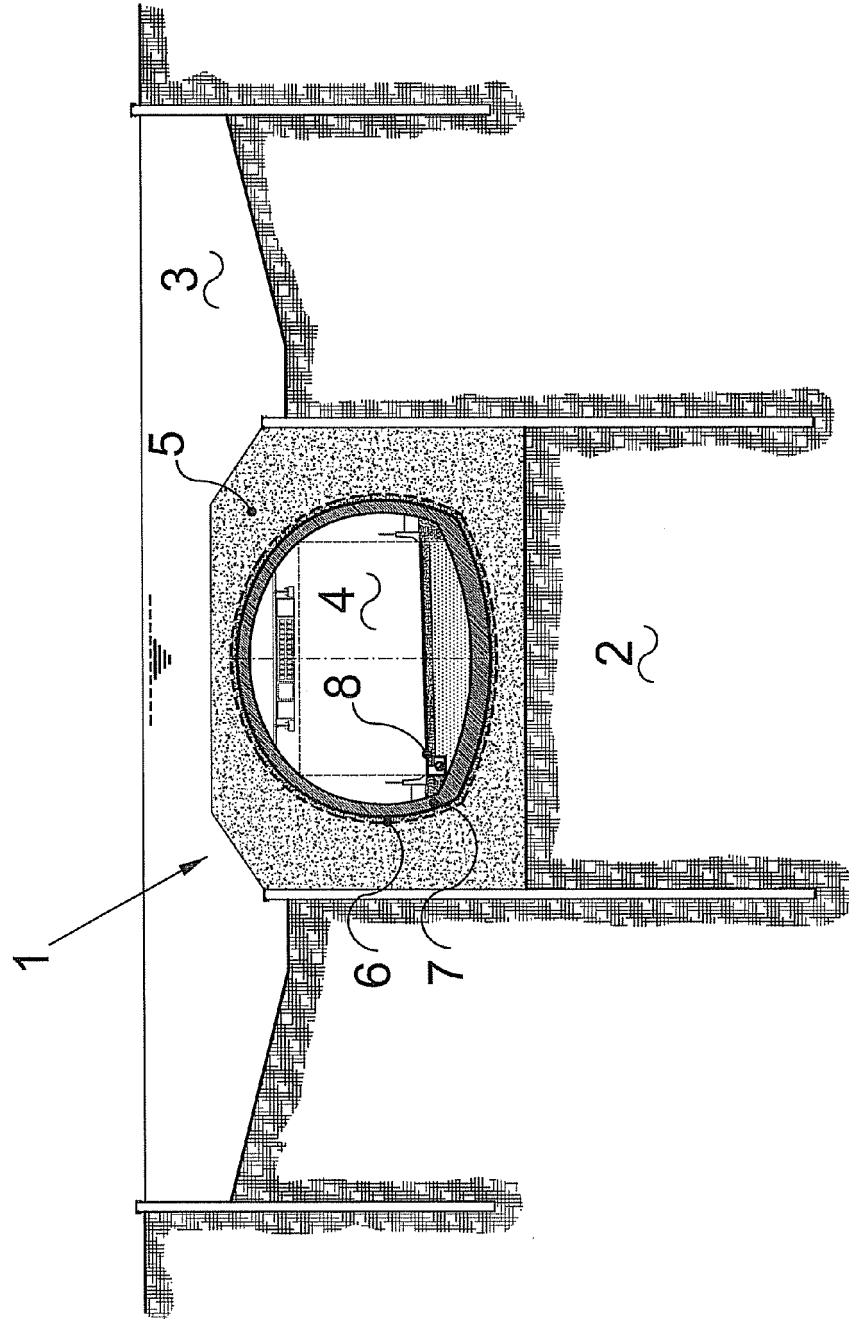


Figure 2

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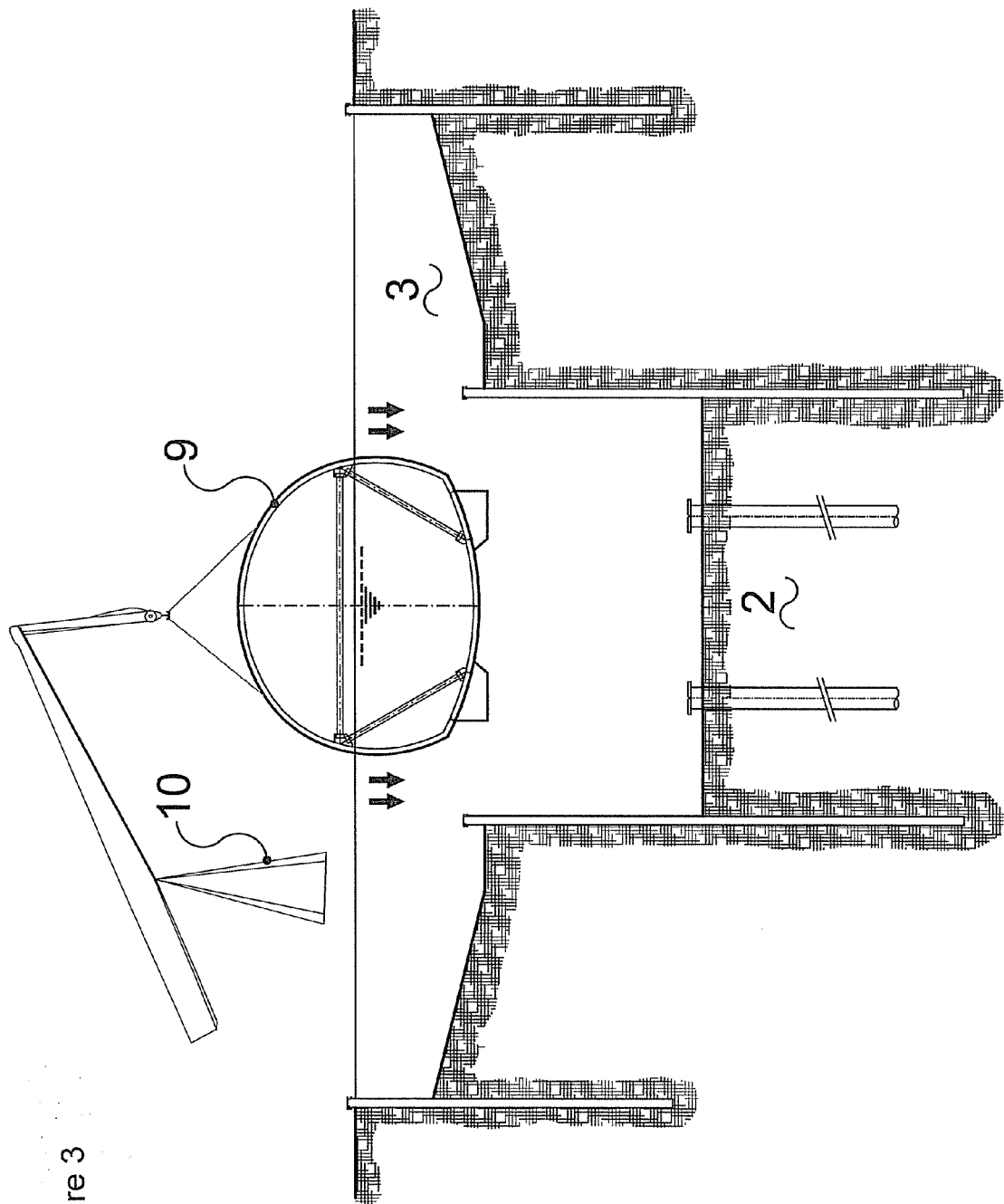


Figure 3

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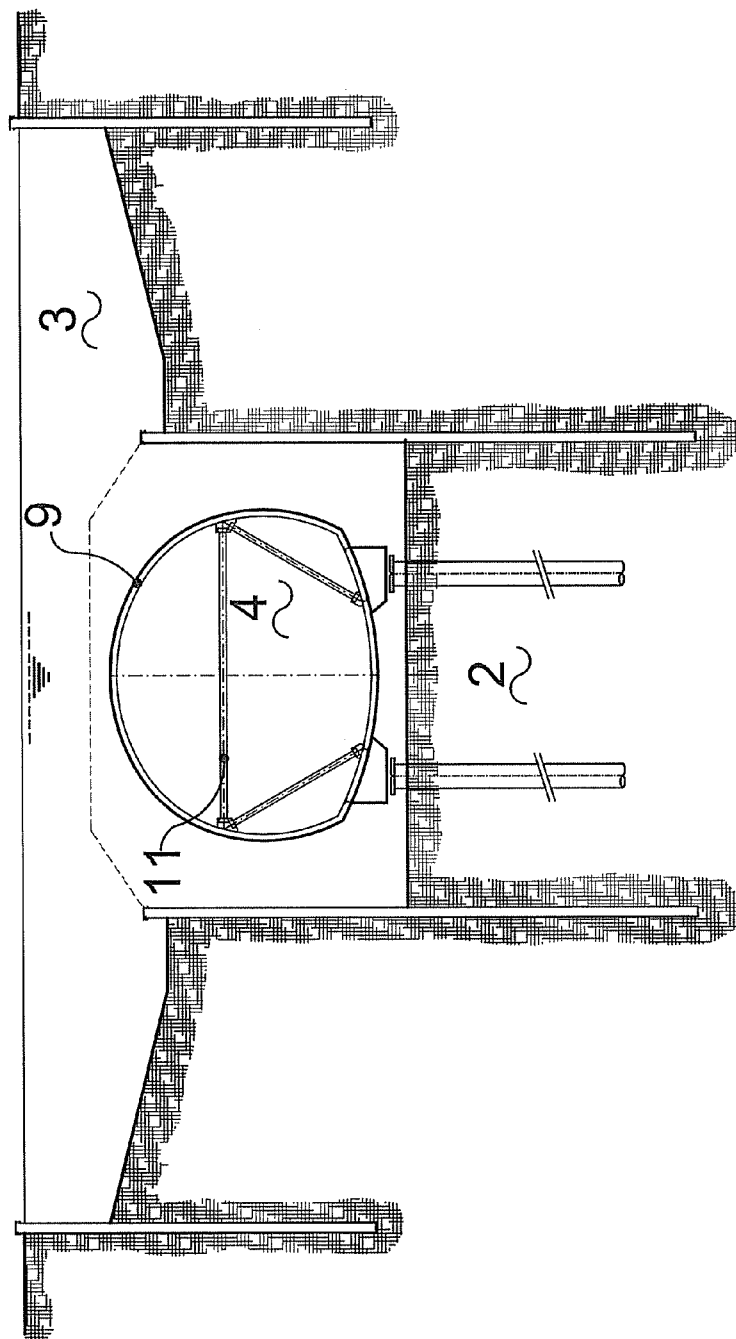
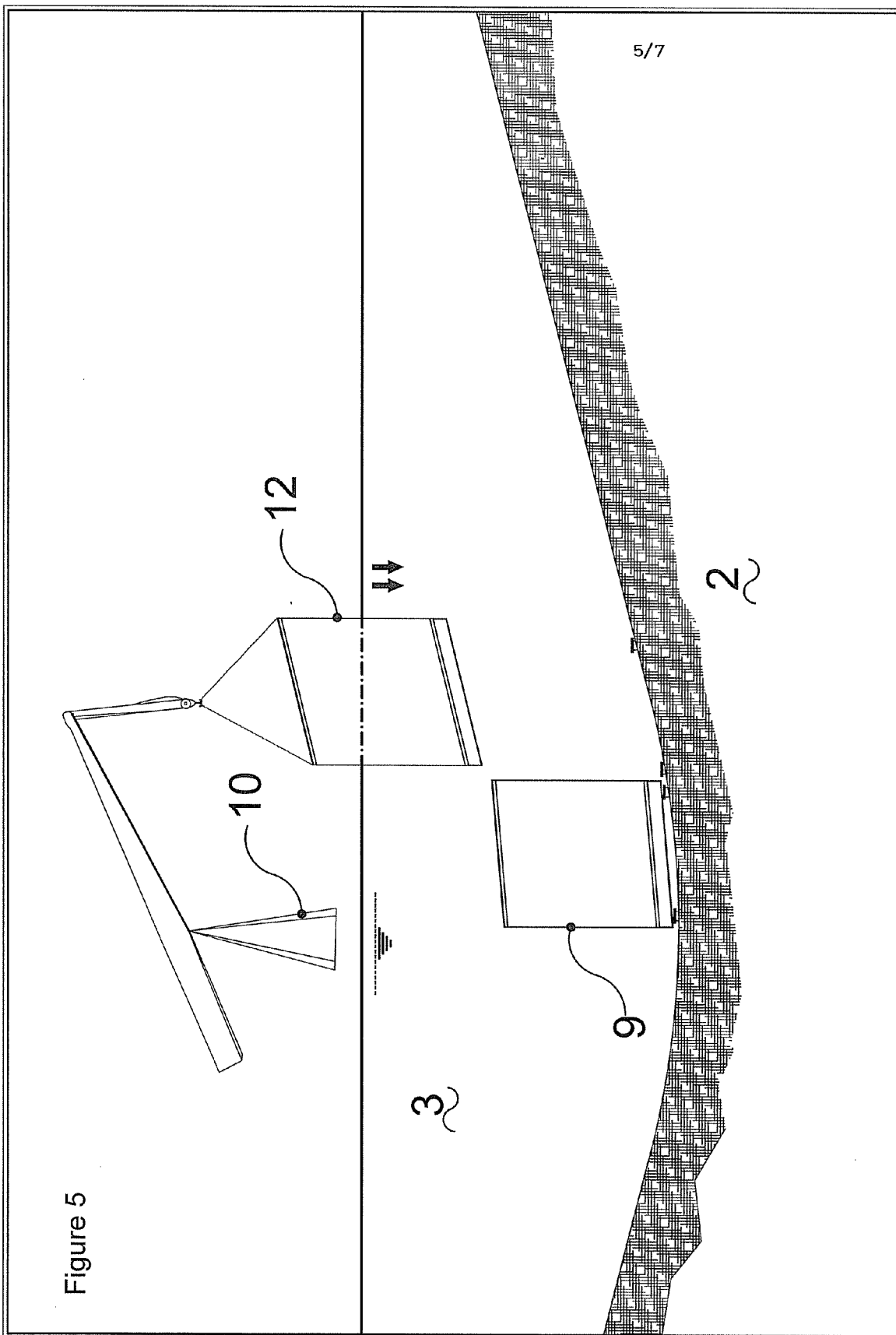
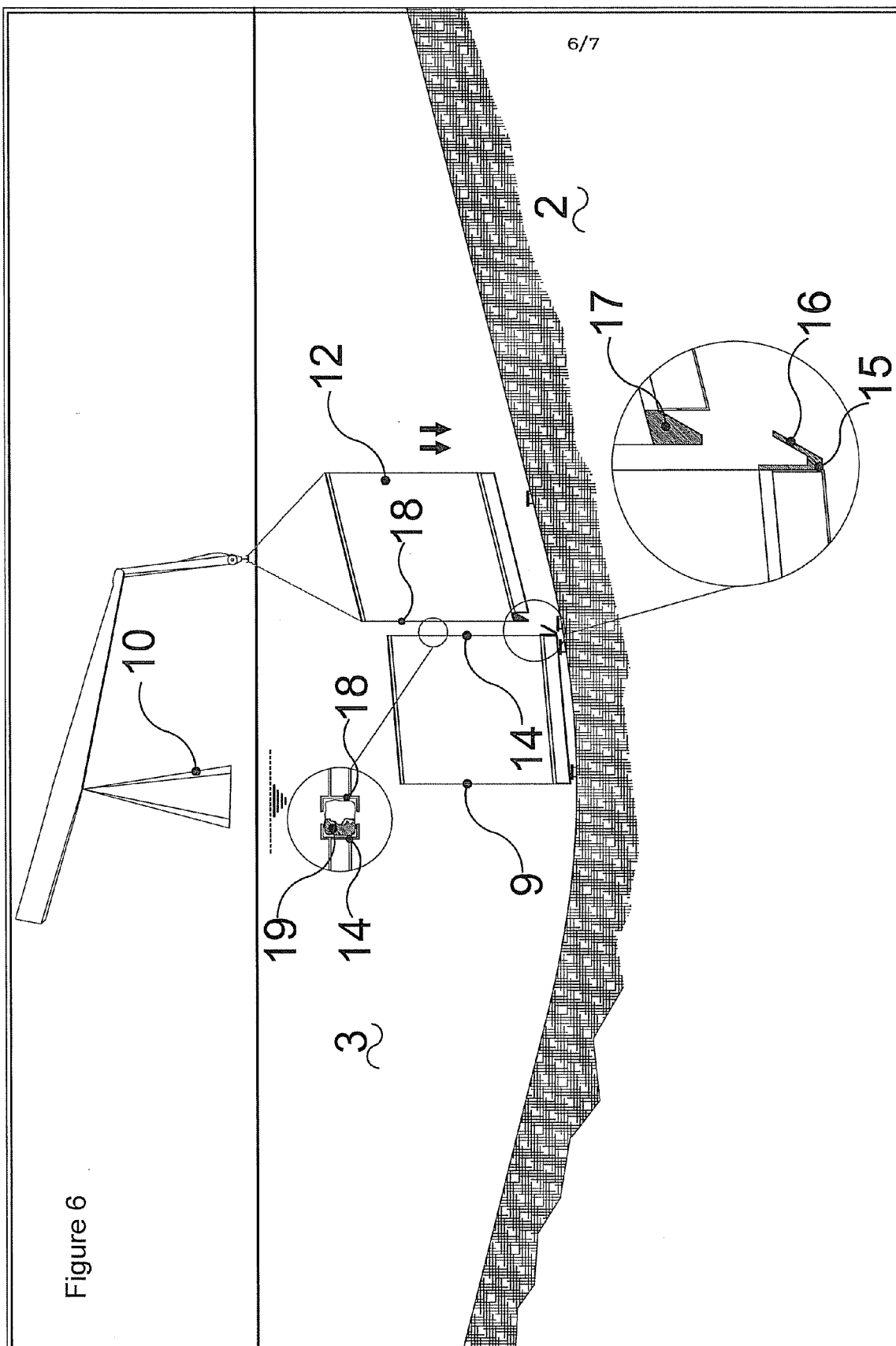


Figure 4





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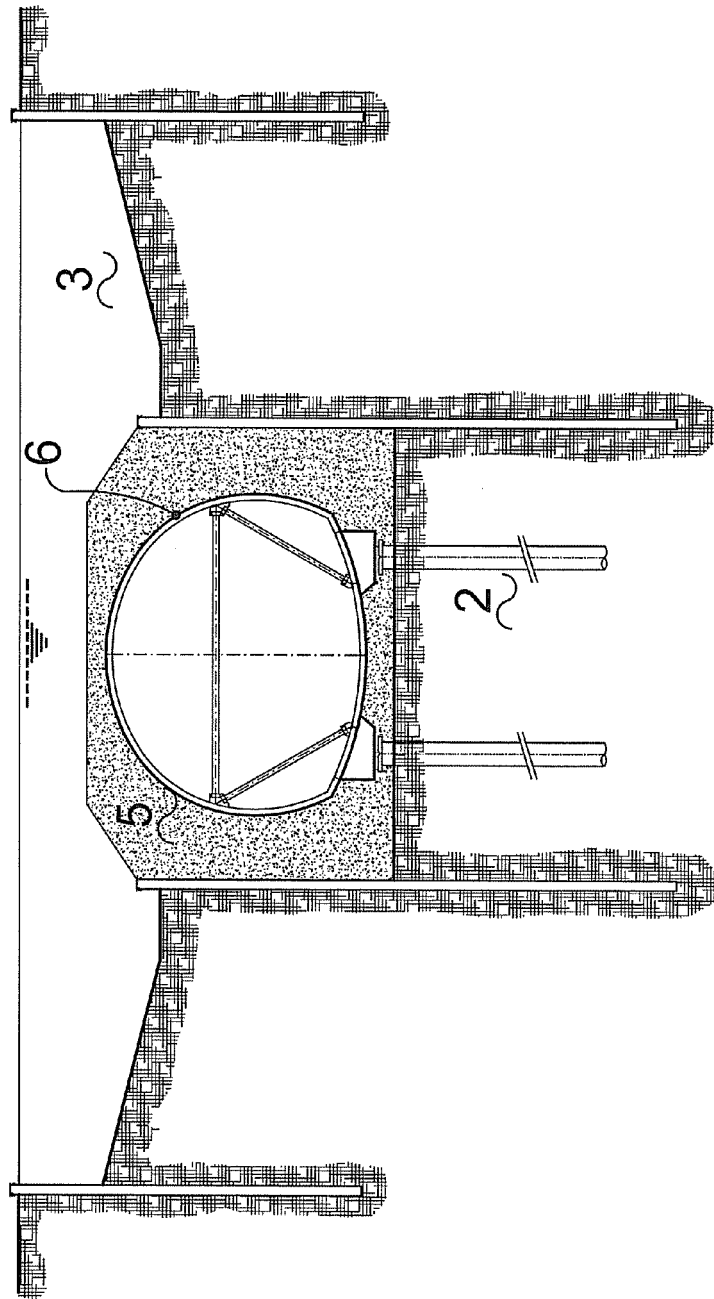


Figure 7



European Patent
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Application Number
EP 07 10 6719

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 31 October 2007	Examiner Nilsson, Lars
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EPO FORM 1503 03 82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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