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(71) Applicant: **CASAGRANDE SpA**
Viale Venezia, 97
I-33074 Fontanafredda (PN)(IT)

(72) Inventor: **Casagrande, Bruno**
Via Malignani 3
I-33074 Fontanafredda (PN)(IT)
Inventor: **Fiorotto, Renato**
Via Maggior Piovesana 7
I-31015 Conegliano (TV)(IT)

(74) Representative: **Petraz, Gilberto Luigi**
G.L.P. S.a.s. di Gilberto Petraz P.le Cavedalis 6/2
I-33100 Udine(IT)

(54) Process to excavate the inverted lower arch in existing tunnels and apparatus to carry out the process.

(57). Process to excavate the inverted lower arch in existing tunnels, tracks (11-111) for vehicles passing within the tunnels (10) being protected by a protective shield (16) placed between the tracks (11-111) and the inner walls of the tunnels (10), the portion of the tracks (11-111) involved in the excavation being made to cooperate with provisional, temporary support means (14), the process providing for performance of the working steps connected with the excavation of the inverted lower arch (13) in existing tunnels (10) without interrupting the normal flow of traffic passing within the existing tunnels (10) in which work is to be done, the working steps connected with the excavation being organized and carried out within the circular space contained between the protective shield (16) and the extrados of the tunnel (10) and below the portion of track (11-111) momentarily upheld by the temporary support means (14).

Apparatus to excavate the inverted lower arch (13) in existing tunnels (10), which employs the above process and consists of:

- a vault-shaped structure (19) able to move on its own runways (20),
- arms (21) to support the excavation equipment,
- excavation equipment (22) and
- means to excavate service channels (34).

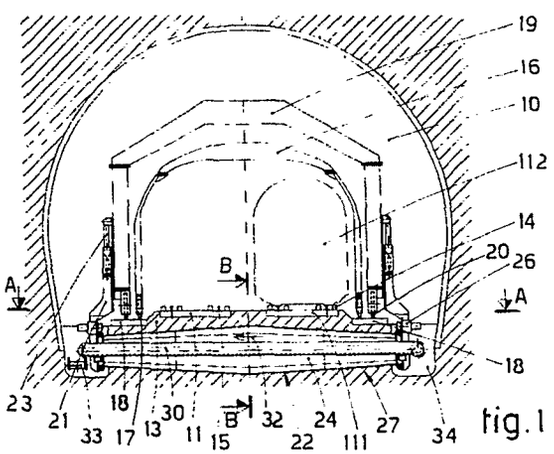

fig.1

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PROCESS TO EXCAVATE THE INVERTED LOWER ARCH IN EXISTING TUNNELS AND APPARATUS TO CARRY OUT THE PROCESS

This invention concerns a process to excavate the inverted lower arch in existing tunnels. To be more exact, this invention concerns a process suitable for the excavation and restoration of the inverted lower arch in existing tunnels without interrupting the flow of vehicles normally passing along the tunnels where work is to be done.

The process of the invention is generally employed equally well in work to enlarge existing tunnels or only repair the existing inverted arch.

The process may also be employed for the excavation and preparation of a new inverted arch in existing tunnels.

The invention concerns also the apparatus which employs the above process.

The state of the art covers the problems connected with the excavation and rehabilitation of the inverted lower arch in existing tunnels. These problems arise substantially from the need to interrupt any flow of vehicles within the tunnels until the excavation and rehabilitation work has been completed.

Such work generally becomes necessary where existing tunnels are to be enlarged, and in cases where the inverted arch has to be re-made because it has collapsed or been damaged or for other reasons.

It follows that alternative plans have therefore to be made which normally envisage the doubling of the tunnel in which work has to be done.

The outcome can be summed up as involving long times for design work and approval of the new plans, the necessity of expropriation of land, environmental problems and the unavoidable performance of new works upstream and downstream for the necessary rectification of the lay-out.

The present applicant has the purpose of overcoming the problems linked to the state of the art and of perfecting a process able to carry out the excavation and rehabilitation, or excavation and preparation, of the inverted arch in existing tunnels without interrupting the flow of vehicles passing into the tunnels.

A further purpose of the invention is to provide an apparatus able to carry out the above process.

The invention is set forth in the main claims 1 and 14, while the dependent claims describe various features of the invention.

The process of the invention provides for the use, within an existing tunnel, of a protective shield through which the traffic is made to pass. This protective shield forms part of the state of the art.

The shield can stretch along the whole length of the tunnel or be restricted to the portion substantially affected by the works. This portion, in the case of a railway line, to which we shall refer in the description that follows, is suitably supported to enable trains to pass through while work is proceeding below it.

The support structures are suitable prepared on each occasion downstream of the portions on which work is being carried on, according to methods belonging to the state of the art.

The excavation works on the inverted arch are conducted with an apparatus which passes along the tunnel and is positioned between the protective hield and the inner wall of the tunnel.

This apparatus carries out the following works continuously for excavation and rehabilitation of an existing inverted arch:

- the making of two lateral excavations parallel to the railway line so as to enable the apparatus itself to pass through;
- excavation of the existing inverted arch for complete demolition of the same;
- removal of debris of the excavated inverted arch from the excavation zone;
- removal of all the excavation debris towards the outside of the tunnel or, at any rate, onto means able to carry the debris out of the tunnel, and
- the casting of a new inverted arch.

When the casting of the new inverted arch has ended, steps are taken to remove the protective shield and to set the railway line and all the service works finally in order.

According to the invention the apparatus suitable to carry out the above process consists of a vault-wise structure bearing below itself the equipment to excavate the inverted arch.

This excavation equipment works beneath the railway line and comprises a rotary drum excavation tool that extends substantially along the whole width of the inverted arch.

With the advance of the vault-wise structure on its own runways, this excavation tool carries on continuously the excavation of the inverted arch, the debris of which is removed by means of the excavation tool itself. For this purpose it comprises incorporated means for removal of debris from the excavated zone so as to transfer the debris onto means for final removal from the tunnel.

The excavation tool possesses not only a rotary motion but also a vertical motion so that it can be adjusted to the thickness of the inverted arch to be excavated.

Shuttering operates in cooperation with the excavation tool in a coordinated manner in the casting of material to form a new inverted arch in the

excavation zone. This shuttering is suitably conformed to constitute a support too for the railway lines above.

Auxiliary means may also be comprised to remove excavated material which may not have been collected by the excavation tool.

The vault-shaped structure is equipped with lateral excavation means to make channels parallel to the railway line which make possible the free forward movement of the excavation tool and the removal of debris from the tunnel; these lateral excavation means obviously work in advance of the excavation tool.

The apparatus of the invention can be included advantageously in a working train carrying out enlargement of existing tunnels; it can work just as well independently if only the repair of an inverted arch is required.

These and other special features will be described better in the description of the invention that follows.

The attached figures, which are given as a non-restrictive example, show the following:-

Fig.1 is a front diagrammatic view of an excavation apparatus according to the invention;

Fig.2 is a section of the apparatus of Fig.1 along the line A-A;

Fig.3 is an enlarged partial section of the apparatus of Fig.1 along the line B-B;

Fig.4 is a front diagrammatic view of a tunnel with the excavation already performed;

Fig.5 is a front diagrammatic view of a tunnel with a new inverted arch.

The figures give an example, as we said above, of the excavation of an inverted arch in an existing railway tunnel, which in this case contains two railway lines.

Railway lines 11-111 are shown in the tunnel 10 for the passage of trains 12-112.

Provisional support means 14 to support rails 15, as in the state of the art, are provided in the zone involved in the excavation of an existing inverted arch 13.

These provisional support means 14, which may consist of bundles of rails or other suitable systems, are positioned in succession along the railway lines 11-111 so as to enable the excavation work to advance continually.

The railway consisting of two lines 11-111 is protected by a protective shield 16 within which the trains 12-112 can pass.

The protective shield 16 may have a minimum indispensable length equal to the portion of the tunnel 10 involved in the works and may include its own runways 17 positioned on supports 18 arranged at the sides of the railway.

If so required, the protective shield 16 may also have a length differing from the portion of the tunnel 10 involved and will have overall dimensions suited to that of the trains 12-112 passing through it.

The apparatus to excavate the inverted arch 13 consists of a vault-shaped structure 19 able to run within the tunnel 10 on its own runways 20 positioned on supports 18.

The vault-shaped structure 19 comprises lateral arms 21 to support excavation equipment 22; these lateral arms 21 can be adjusted vertically, by jacks 23 for instance, so as to adapt the action of the excavation equipment 22 to the thickness of the inverted arch 13.

The vertical displacement of the arms 21 can be carried out continuously during the whole excavation work.

The excavation equipment 22 consists of a drum 24 capable of being rotated about its own axis according to the arrow 25 by a motor 26, advantageously a hydraulic motor.

The drum 24 extends substantially along the whole width of the inverted arch 13 and has an outer conformation suitable to obtain the desired final profile of the inverted arch 13 as an element to complete the circumference of the tunnel 10. In the example shown the outer conformation of the drum 24 conforms to a double cone.

The drum 24, which is hollow within, includes on its outside excavation tools 27, which cooperate with slits 28 made in the periphery of the drum 24 so as to enable the materail excavated to fall within the drum 24. This fall takes place by gravity and the material is held momentarily by vanes 29 suitably arranged inside the drum 24.

When the material reaches the neighbourhood of the upper part of the drum during rotation thereof, it falls from the drum 24 and the vanes 29 onto a discharge means within the drum; this discharge means is positioned parallel to the axis of the drum 24 and in this case is a first conveyor belt 30 driven by a motor 31 in the direction of the arrow 32.

According to a varaint at least one stationary worm is included within the drum 24 and is arranged in such a way that it skims the inner surface of the drum 24. The excavated material is discharged sideways by the friction caused by the relative movements of the rotary drum and stationary worm. All embodiments provide for discharge of the material on one side or on the opposite side or on both sides.

The first conveyor belt 30 emerges laterally from the drum 24 and cooperates with a second conveyor belt 33 that removes the excavated material towards the outlet of the tunnel 10.

The second conveyor belt 33, being positioned beneath the plane of the railway lines 11-111, can cooperate conveniently with elements that dis-

charge onto vehicles which carry the material out of the tunnel 10 if there is enough space available.

The lateral end portions of the drum 24 and of the first conveyor belt 30 and also the lower ends of the support arms 21 and the second conveyor belt 33 can move in service channels 34 excavated beforehand parallel to and at the sides of the railway. These service channels 34 are obtained advantageously by the action of excavation arms (not shown in the figures) solidly fixed to the vault-shaped structure 19.

These excavation arms obviously work in the direction of forward movement 35 of the vault-shaped structure 19 in advance of the action of the equipment 22 that excavates the inverted arch 13.

Shuttering 36 works in cooperation and co-ordination with the movement of the excavation equipment 22 so as to make possible the casting of material 37 which will form the new inverted arch 113. This shuttering 36 may be conformed advantageously to provide a support for the railway lines 11-111 above; for this purpose it may consist, for instance, of two halves 136-236 which can be coupled together telescopically and actuated by an inner screw 40.

A discharge worm screw 41 may be connected advantageously to the shuttering 36 and be suitable for lateral removal of debris not collected by the drum 24.

Fig.4 shows the situation in the zone where excavation work on a pre-existing inverted arch 13 takes place.

Fig.5 shows the situation after the new inverted arch 113 has been cast, together with the positioning of ballast 38, the arch 113 blending with the inner lining 39 of the tunnel 10.

Claims

1 - Process to excavate the inverted lower arch in existing tunnels, tracks (11-111) for vehicles passing within the tunnels (10) being protected by a protective shield (16) placed between the tracks (11-111) and the inner walls of the tunnels (10), the portion of the tracks (11-111) involved in the excavation being made to cooperate with provisional, temporary support means (14), the process being characterized in that it provides for performance of the working steps connected with the excavation of the inverted lower arch (13) in existing tunnels (10) without interrupting the normal flow of traffic passing within the existing tunnels (10) in which work is to be done, the working steps connected with the excavation being organized and carried out within the circular space contained between the protective shield (16) and the extrados of the tunnel (10) and below the portion of track (11-111) momentarily upheld by the temporary support means (14).

2 - Process as claimed in Claim 1, whereby the working steps connected with the excavation of the inverted lower arch (13) in existing tunnels (10) consist of:
- excavation of lateral service channels (34) parallel to the tracks (11-111),
- excavation of the existing inverted arch (13);
- removal of the debris of excavation of the inverted arch (13) from the excavation zone;
- discharge of the debris of all the excavations towards the outside of the tunnel (10), and
- casting the new inverted arch (113),
the working steps being carried out continuously in a desired momentary succession by an apparatus able to move along the tunnel (10).

3 - Process as claimed in Claim 1 or 2, whereby the excavation of the inverted arch (13) may be a coordinated step in an operation to enlarge existing tunnels (10).

4 - Process as claimed in Claim 1 or 2, whereby the excavation is carried out so as to lay a new inverted arch (13).

5 - Process as claimed in any claim hereinbefore, whereby the excavation of the inverted arch (13) is carried out on a frontage corresponding to the width of the inverted arch (13) itself.

6 - Process as claimed in any claim hereinbefore, whereby the position for excavating the inverted arch (13) may be varied according to the thickness thereof.

7 - Process as claimed in any claim hereinbefore, whereby the removal of the excavated material of the inverted arch (13) takes place laterally to the tracks (11-111).

8 - Process as claimed in any claim hereinbefore, whereby the removal of the excavated material of the inverted arch (13) takes place substantially at the same time as the excavation of the same.

9 - Process as claimed in any claim hereinbefore, whereby the removal of the excavated material of the inverted arch (13) is carried out by the means that perform the excavation.

10 - Process as claimed in any claim hereinbefore, whereby the discharge of the excavated material of the inverted arch (13) takes place on a plane located below the tracks (11-111).

11 - Process as claimed in any claim hereinbefore, whereby when the work of excavation of the inverted arch (13) has ended, the excavation possesses a definitive configuration.

12 - Process as claimed in any claim hereinbefore, whereby the excavation of' the service channels (34) is carried out at the same time as, but in a position in advance of, the excavation of the inverted arch (13).

13 - Process as claimed in any claim herein-

before, whereby shuttering (36) for casting (37) the new inverted arch (113) is employed as a support for the railway tracks (11-111).

14 - Apparatus to excavate the inverted lower arch (13) in existing tunnels (10), which employs the process of the claims hereinbefore and is characterized in that it consists of:
- a vault-shaped structure (19) able to move on its own runways (20),
- arms (21) to support the excavation equipment,
- excavation equipment (22) and
- means to excavate service channels (34).

15 - Apparatus as claimed in Claim 14, in which the support arms (21) can be adjusted vertically.

16 - Apparatus as claimed in Claim 14 or 15, in which the excavation equipment (22) consists of:
- a hollow rotary drum (24),
- means (26) to actuate the drum (24),
- excavation tools (27),
- means (30) to remove debris, and
- means (31) to actuate the removal means (30).

17 - Apparatus as claimed in any of Claims 14 to 16 inclusive, in which the rotary drum (24) comprises on its periphery slits (28) that cooperate with the excavation tools (27).

18 - Apparatus as claimed in any of Claims 14 to 17 inclusive, in which the rotary drum (24) comprises internal vanes (29) for temporary storage of excavation debris.

19 - Apparatus as claimed in any of Claims 14 to 18 inclusive, in which the debris removal means (30) are located within the rotary drum (24).

20 - Apparatus as claimed in any of Claims 14 to 19 inclusive, in which the debris removal means (30) consist of a conveyor belt.

21 - Apparatus as claimed in any of Claims 14 to 19 inclusive, in which the debris removal means (30) consist of at least one stationary worm.

22 - Apparatus as claimed in any of Claims 14 to 21 inclusive, in which the length of the rotary drum (24) is coordinated with the width of the inverted arch (13) to be excavated.

23 - Apparatus as claimed in any of Claims 14 to 22 inclusive, in which the shuttering (36) has a telescopic structure (136-236).

24 - Apparatus as claimed in any of Claims 14 to 23 inclusive, in which the shuttering (36) comprises screw-type actuation means (40).

25 - Apparatus as claimed in any of Claims 14 to 24 inclusive, in which the shuttering (36) comprises lateral worm screw means (41) to discharge excavated debris.

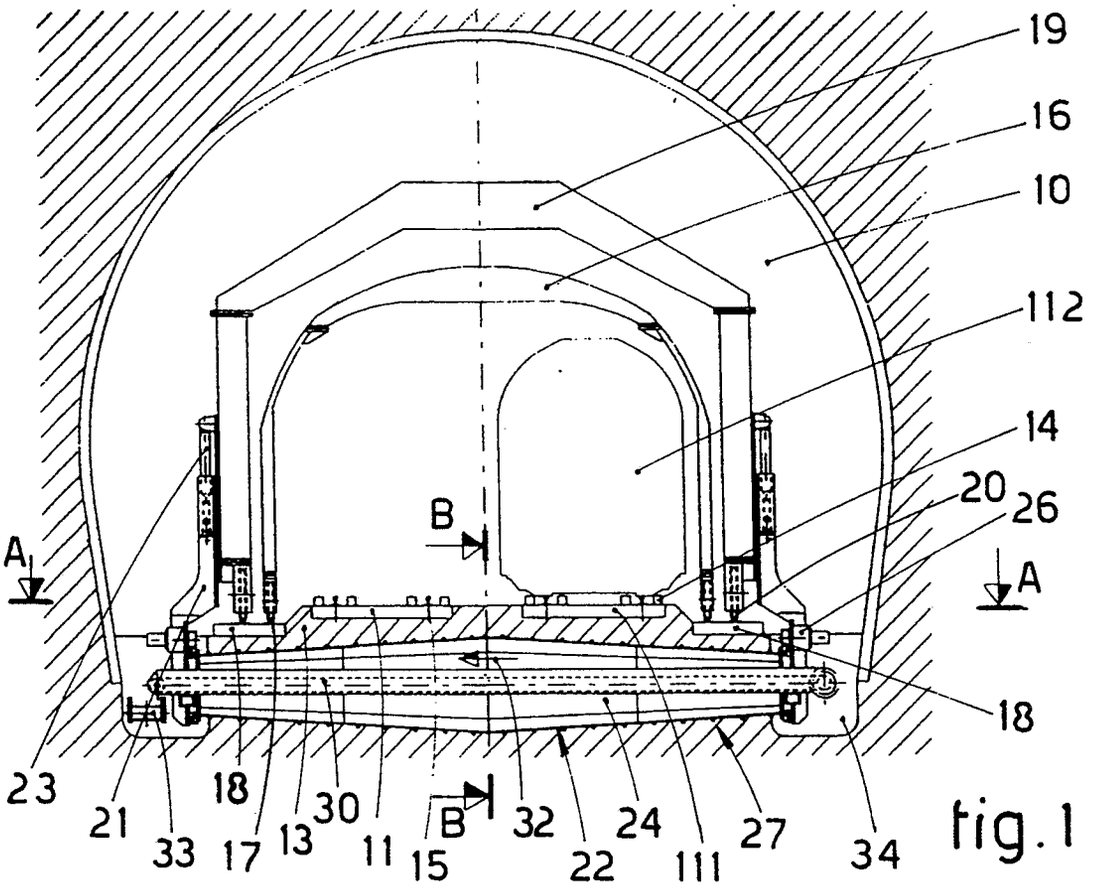

fig.1

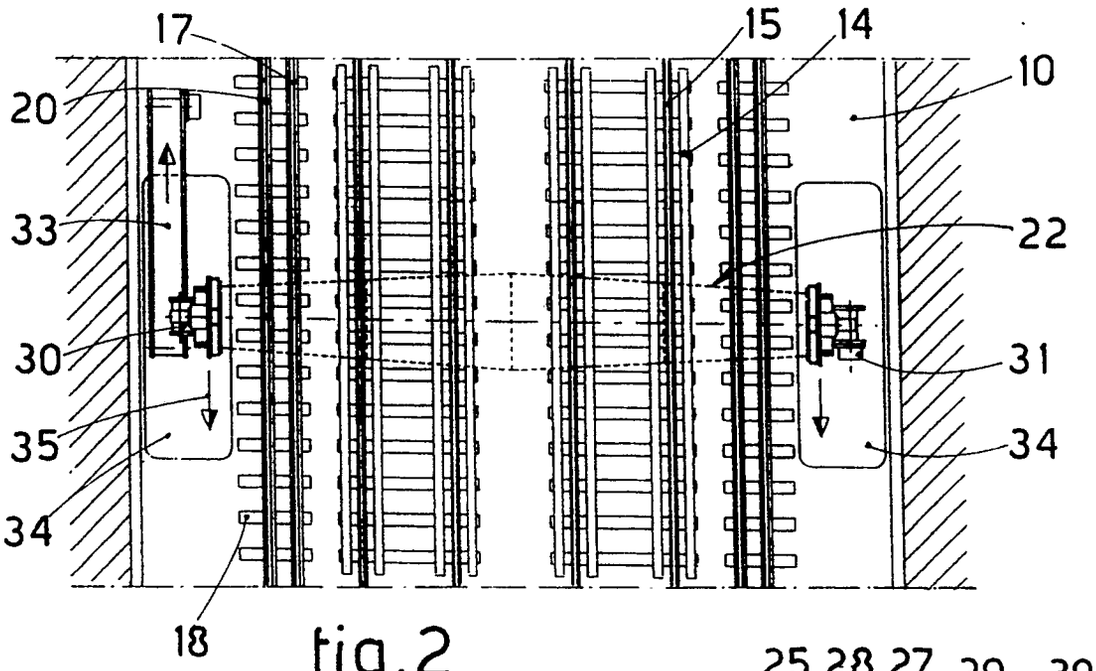

fig.2

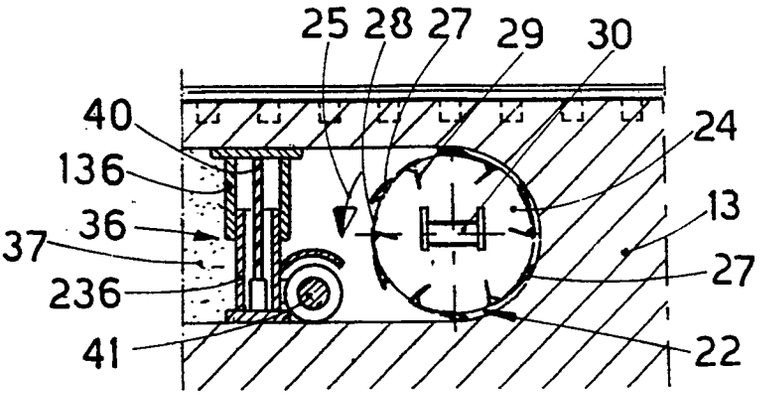

fig.3

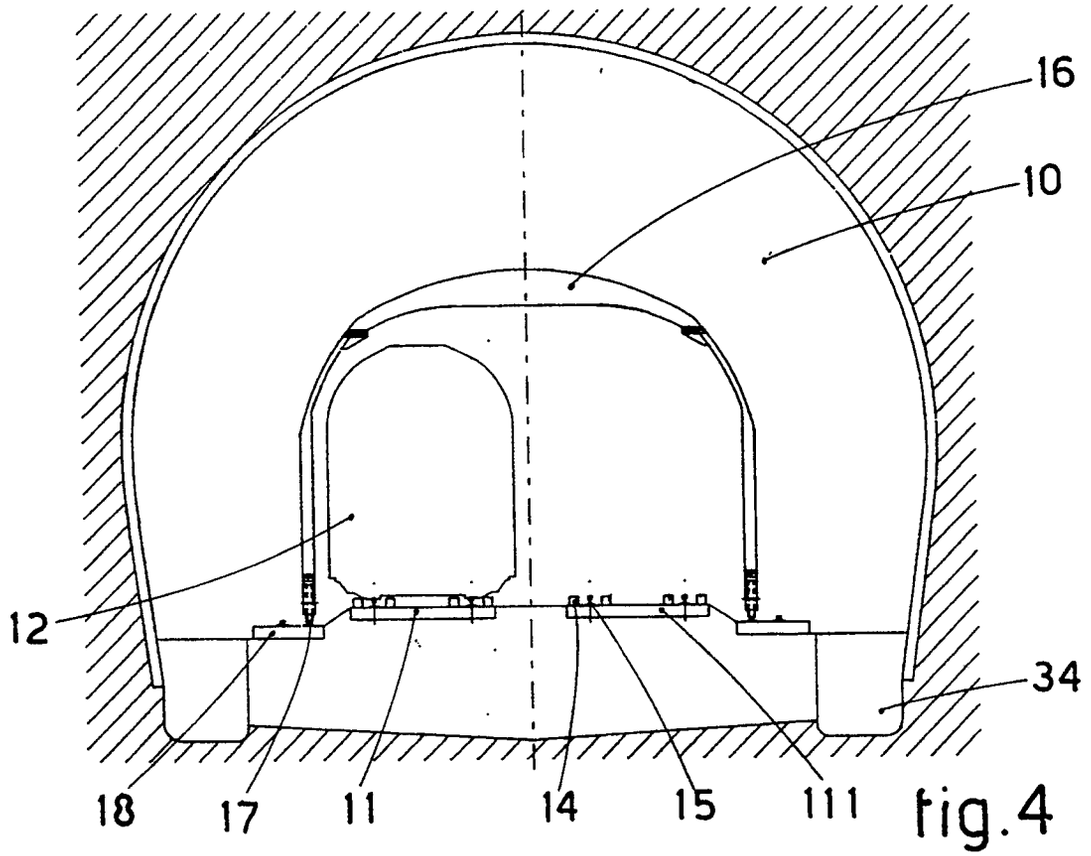

fig.4

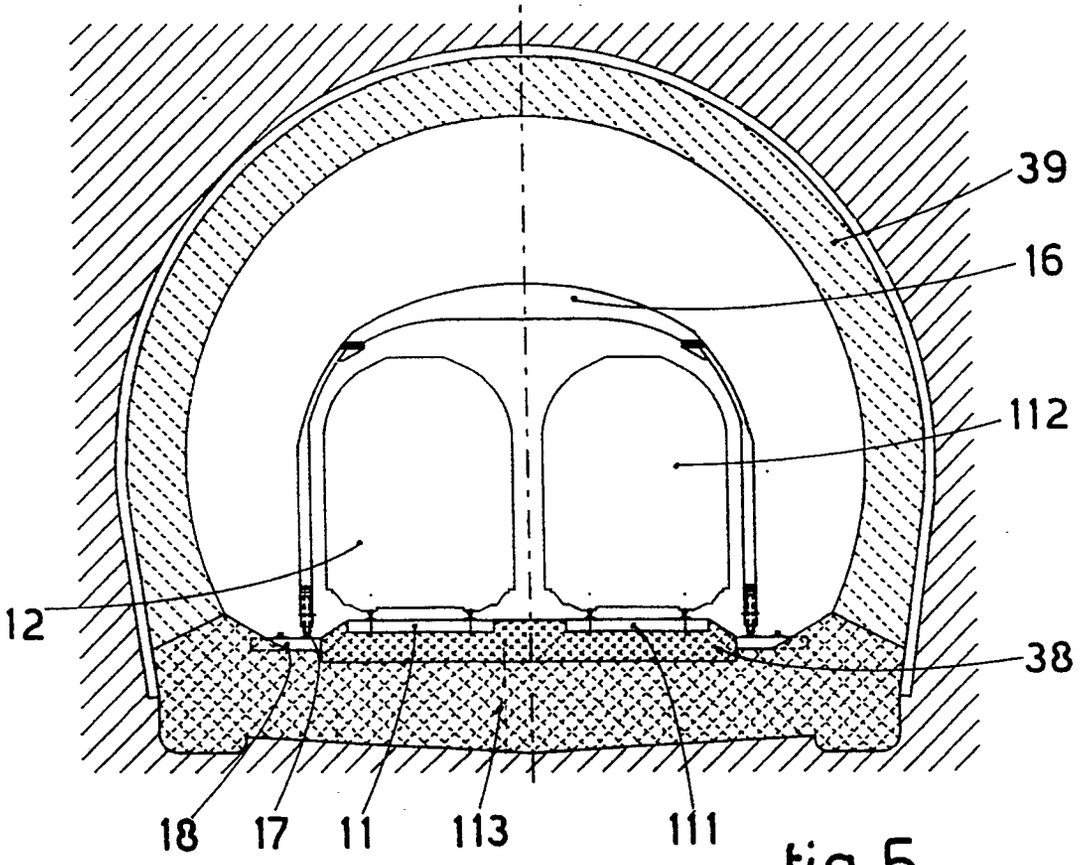

fig.5