Nov. 29, 1932. J. B. GOLDSBOROUGH 1,889,599

METHOD OF FILLING VOIDS IN SOIL

Filed May 10, 1930

Fig. 1.

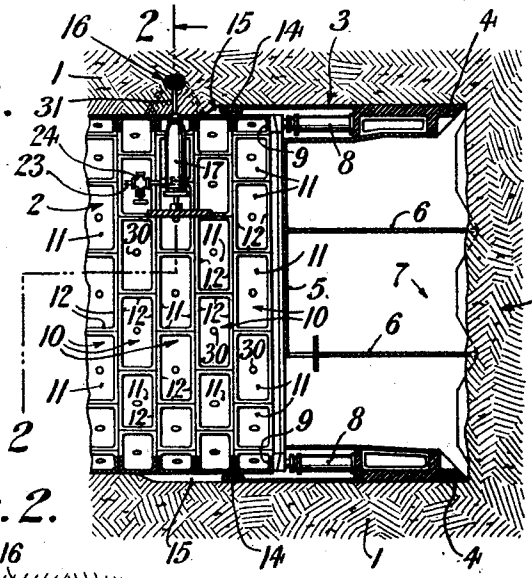


Fig. 4.

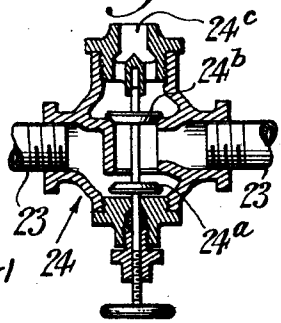


Fig. 5.

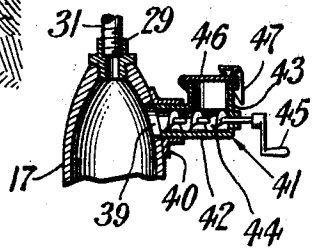


Fig. 2.

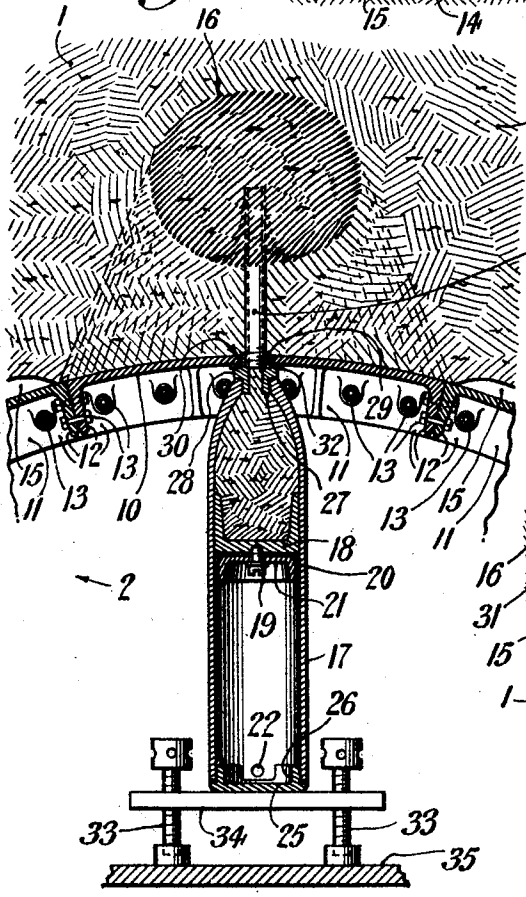
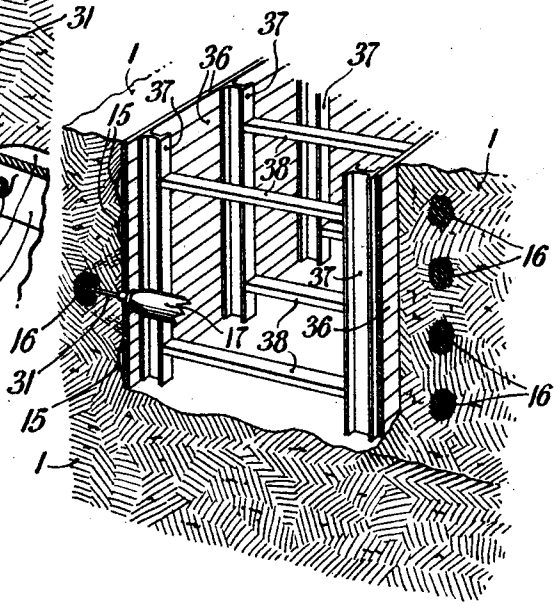


Fig. 3.



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UNITED STATES PATENT OFFICE

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METHOD OF FILLING VOIDS IN SOIL

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This invention relates to a method of filling voids in soil, such as occur during certain tunnelling and excavating operations.

In the construction of tunnels by means of shields which are forced through the soil by means of jacks reacting against the permanent structural elements of the tunnels, which are usually rings made up of connected segments, annular voids are created around the permanent elements immediately following the tails of the shields as the latter are advanced relatively to the last formed ring sections of the tunnel.

Various methods of filling such voids have been employed, such for instance as forcing grout from the interior of the tunnel through holes in its ring segments into the surrounding void, or inserting material such as gravel or sand, into the void by an air blast and impacting it to such a density as will prevent settlement of the surrounding soil into the void.

The former method has the disadvantage that the liquid condition of the grout causes it to flow from the void into the space between the tail of the shield and the tunnel rings lying within this portion of the shield. It may even flow so far as to run back into the working chamber of the shield.

The latter method has the disadvantage that the material forced into the void by the air blast is deposited only in the vicinity of the holes in the segments and an additional operation of forcing grout into the void to fill the remaining empty spaces must ordinarily be performed, which is open to the same danger of the grout flowing back into the tunnel as referred to above.

In the construction of excavations in which retaining walls of sheathing are employed, voids usually occur behind the sheathing which if not filled, result in settlement of the adjacent soil with possible damage to structures thereon. These voids are ordinarily filled by tamping material into them through slits or other openings in the sheathing or by forcing grout behind the same. Tamping methods are laborious and expensive and the use of grout is unsatisfactory on account of the time required for it to harden and the difficulty of controlling its flow.

It is an object of this invention to provide for filling voids in soil resulting from tunnelling and excavating operations and which avoids the disadvantages of prior methods and enables the voids to be quickly, inexpensively and completely filled with a minimum amount of labor.

This general object of the invention is attained by forcibly injecting into the soil beyond the void a sufficient quantity of a substantially incompressible material, such as clay, to displace the soil in the direction of the void and thereby fill it. The quantity of material used for this purpose and the distance beyond the void at which it is forced into the surrounding soil will depend upon the volume of the void and the nature of the soil which is to be forced into the void by the reaction of the material against the soil lying beyond it. In general the quantity of material and the point at which it is applied to the soil will be such that the lines of action of the resultant soil displacing forces created by the forcible injection of the material into the soil will diverge over a considerable area to displace enough soil to fill the entire void or a substantial portion of it.

The particular nature of the invention as well as other objects and advantages thereof will appear most clearly from a description of certain preferred embodiments thereof as shown in the accompanying drawing in which

Fig. 1 is a longitudinal sectional view of the advance end of a tunnel showing an application of the invention to the filling of the voids created by the forward movement of the shield with respect to the tunnel;

Fig. 2 is an enlarged transverse sectional view along the line 2—2 of Fig. 1 of a portion of the tunnel and the apparatus for injecting material into the soil;

Fig. 3 is a perspective view partly in section showing an application of the invention to filling voids behind the retaining wall of an excavation;

Fig. 4 is an enlarged sectional view through the control valve of the compressed air line; and

Fig. 5 is a fragmentary sectional view of a portion of the container for the substantially incompressible material, showing means for charging the same with such material.

In Figs. 1 and 2, 1 represents the soil through which a tunnel 2 is to be driven by means of a shield 3 which is provided with a cutting edge 4, a diaphragm 5 and platforms 6 in the working chamber 7. The shield is advanced through the soil by hydraulic jacks 8 working against abutments 9 in the interior of the shield.

The jacks react against the front edge of the forward one of a series of rings 10 forming the permanent lining of the tunnel and each composed of a plurality of segments 11 provided with flanges 12 by which the segments of each ring are connected to each other and to the segments of adjacent rings by means of bolts 13 in a well known manner.

The tail portion 14 of the shield extends rearwardly around a number of the rings of the tunnel and is freely movable with respect to the rings. As the shield is advanced its greater diameter as compared with the rings of the tunnel causes the formation of an annular void 15 around the rings, which heretofore has been filled by methods as described in the introductory portions of this specification.

In accordance with this invention the void is filled by forcibly injecting into the soil beyond the void separate quantities of material, such as clay, to form soil displacing masses 16 which by their reaction from and upon the surrounding soil 1 force the soil between them and the void into the latter to fill it.

Any suitable apparatus may be employed for forcing the material into the soil or it may be done by manual tamping if desired. As shown herein the apparatus consists of a receptacle or flask 17 similar to those employed for holding compressed gases. It is provided with a piston 18 having attached thereto by a screw 19 a washer 20 of leather or other suitable material and a retaining member 21. The piston is adapted to be forced outwardly by compressed air supplied through a part 22 at the end of the receptacle and a pipe 23 leading from an air pump or a compressed air reservoir and provided with a valve 24 for controlling the admission and exhaustion of air to the receptacle. The end of the receptacle is closed by a screw cap 25, the threaded flange 26 of which also serves to limit the inward movement of the piston so that there is space between it and the cap to permit entrance of compressed air to move the piston.

As shown in Fig. 4, the valve 24 has two internal valves 24*a* and 24*b*, and when the former is open the latter is closed, so that the compressed air will flow to the port 22 to enter the flask 17 and drive the piston to expel the substantially incompressible material from the flask. After this has been accomplished, and the clay mass has been formed in the soil to displace some of the earth to enter the void, the valve 24 may be operated to carry the internal valve 24*a* against its seat and to unseat the internal valve 24*b*, whereupon the compressed air in the flask 17 will flow back through the port 22 to the valve 24 and by the now open internal valve 24*b* to exhaust to the atmosphere through the port 24*c*.

The tapering or discharge end of the receptacle is provided with a screw nozzle cap 27 having a flange 28 and an extension 29 adapted to be placed in the hole 30 ordinarily provided in each segment 11 and heretofore used for attachment of a pipe through which grout or gravel is supplied to the external void. A pipe 31 is attached to the extension and serves to convey the material ejected from the receptacle into the soil at the desired point where the mass 16 is to be formed. A washer 32 is placed between the flange 28 and the inner surface of the segment to make a tight joint at this point to prevent leakage from the tunnel of the compressed air usually employed therein. The receptacle is held in place by the pressure of the compressed air in the tunnel as well as by jacks 33 passing through a bar 34 at the end of the receptacle and reacting against a scaffold 35 in the tunnel. This scaffold may be mounted, if desired, upon the well-known travelling stage that is ordinarily present in the tunnel being constructed to afford platform accommodations for workmen and materials back of the cutting shield.

In practice, an appropriate supply of flasks 17 are kept at hand, and before and after being placed into the operative position shown in Fig. 2 have their nozzle caps 27 removed. The flasks are charged with clay that is entered through the then open orifice at the tapered end of the flask.

Considering the use of only one flask 17, though a battery of them may be used simultaneously, it is mounted as indicated in Figs. 1 and 2, and the valve 24 is opened. Thereupon, compressed air flows from the supply-pipe 23 through the port 22 into the interior of the flask 17. At this time, the piston 18 will be near the port 22 and will be driven by the compressed air toward the tapered end of the flask 17.

The clay within the flask will consequently be extended from it, passing through the nozzle cap 27 and the pipe 31, to emerge from the latter at a suitable distance from the exterior of metallic cylinder formed of the permanent tunnel rings 10. In assuming a mass formation of adequate proportions, the clay is increasingly less able to advance through the soil in a direction away from the tunnel, but, due to the presence of the

void 15 next to the tunnel rings 10, as shown at the bottom of Fig. 1, the clay continues to expand and advance towards the tunnel rings.

By making pipe 31 of approximately the most suitable length for the character of the soil encountered, the quantity of soil between the clay mass and the exterior of the tunnel rings 10 will be such that it will yield to the force exerted thereupon by the clay. Such force is graphically indicated by dotted lines in Figs. 1 and 2, as acting upon a volume of soil between the clay mass and the tunnel rings 10, whereby this soil has been displaced and forced against a portion of the permanent metallic shell formed of the tunnel rings 10. Within the area affected the void 15 is thus removed and replaced by compacted soil that has been pressed against the permanent metallic shell of the tunnel by the clay mass.

Subsequent different positioning of the flask 17 and its associated pipe 31 from one segment 11 of the tunnel rings 10 to another, or the application of a battery of flasks 17 to a plurality of tunnel ring segments 11, will entirely remove the void surrounding the successive tunnel rings 10 after the cutting shield has advanced. Instead the entire exterior of the permanent metallic shell of the tunnel will finally be surrounded by compacted soil.

In the case of such straight sided excavations as are indicated by Fig. 3, sheathing 36 commonly lines the earth walls and is backed by vertically extending studs 37, shown as I-beams, the studs of opposing walls being mutually reinforced by horizontal cross braces 38. The sheathing 38 has a hole placed in it for each application of the apparatus, the pipe 31 being passed therethrough to project a suitable distance into the soil beyond the sheathing and the nozzle cap of the flask 17 being fitted into the hole.

The succeeding operations correspond to those already described in connection with the removal of the voids about the exterior of the permanent metallic shells of tunnels. Hence, it will be clear that the soil between the clay mass 16 and the sheathing 36 will be displaced by the reaction of the clay against the soil beyond it, so that the voids 15 will be replaced by compacted soil, and bear uniformly against the inside of the sheathing as shown at the right in Fig. 3.

There may be circumstances in which it will be desirable to reload the flask 17 without removing it from its applied position, and to permit this the shell of the flask is provided with an aperture 39 in register with which is a tubular fitting 40 riveted or otherwise secured to the outer surface of the flask, as shown in Fig. 5. An injector 41 has a tubular portion 42 of its casing screwed into the fitting 40, and at its other end is provided with a hopper 43, into which clay may be inserted. A conveyer screw 44 in the tubular portion 42 of the injector may be turned, as by a handle 45, so that the inserted clay will be positively fed into the flask 17.

After the flask has been charged with clay, the hopper 43 may be closed by a stout lid 46, which is then held locked to the hopper by a rugged latch 47. Under these conditions, the clay cannot escape through the hopper as the piston drives it from the flask. Any other suitable clay-admitting means may be used, if desired, so long as it easily admits the clay to the flask, and prevents its escape through such means as the piston acts to expel the clay into the soil. The injector may be used on different flasks and the fitting 40 may be closed by a threaded plug when the injector has been removed.

While a preferred method embraced by the invention has been illustrated and described, it will, of course, be understood that various changes in the ways and means of exercising the invention may be indulged in without departing from the spirit of the invention as defined by the appended claims.

I claim:

1. The method of filling voids in the soil adjacent to structural elements which consists in forcing substantially incompressible material into the soil beyond the voids under sufficient pressure to cause it to displace the soil in the direction of the voids to fill the latter.

2. The method of filling a void resulting from excavating operations which comprises forcibly injecting into the soil in the vicinity of the void one or more masses of substantially incompressible material to displace in the direction of the void a quantity of soil equal to the volume of the void to fill the latter.

3. The method of filling a void in the soil adjacent to a structural element which comprises impacting substantially incompressible material into the soil in such quantity and at such distance that the lines of action of the resultant soil-displacing forces diverge over a considerable area and displace soil and cause it to enter the void and bear against the structural element.

4. The method of filling a void in soil on one side of a wall from an opposite exposed side of the wall which comprises transferring at a sufficient number of places substantially incompressible material from the exposed side of the wall through the wall and therebeyond under pressure until the transferred material reacts against the soil and displaces soil in the direction of the wall to fill the void.

5. The method of filling a void in soil on one side of a wall from an opposite exposed side of the wall which comprises sealing substantially incompressible material on and from the exposed side of the wall at a suffi-

cient number of places, and placing it into communication with the other side of the wall, applying force to said material to inject it into the soil beyond the wall to cause said material to react against part of the soil to displace soil between itself and the void into the latter.

6. The method of filling voids in soil external to a tunnel wall having a plurality of annularly and longitudinally spaced apertures which comprises establishing paths from said apertures through the soil to beyond a void-containing zone adjacent thereto and applying charges of substantially incompressible material to different apertures so that such material can only be displaced through the wall from the interior of the tunnel, applying pressure to said charges of said material to transfer the same from the interior of the tunnel through the wall thereof and beyond said void-containing zone to react against the soil and force the soil between said masses of material and the tunnel wall toward the latter to fill any existing void.

In testimony whereof I affix my signature.

JOHN B. GOLDSBOROUGH.