Oct. 14, 1930. W. F. WEBB 1,778,099

METHOD FOR APPLYING CONCRETE TO TUNNELS

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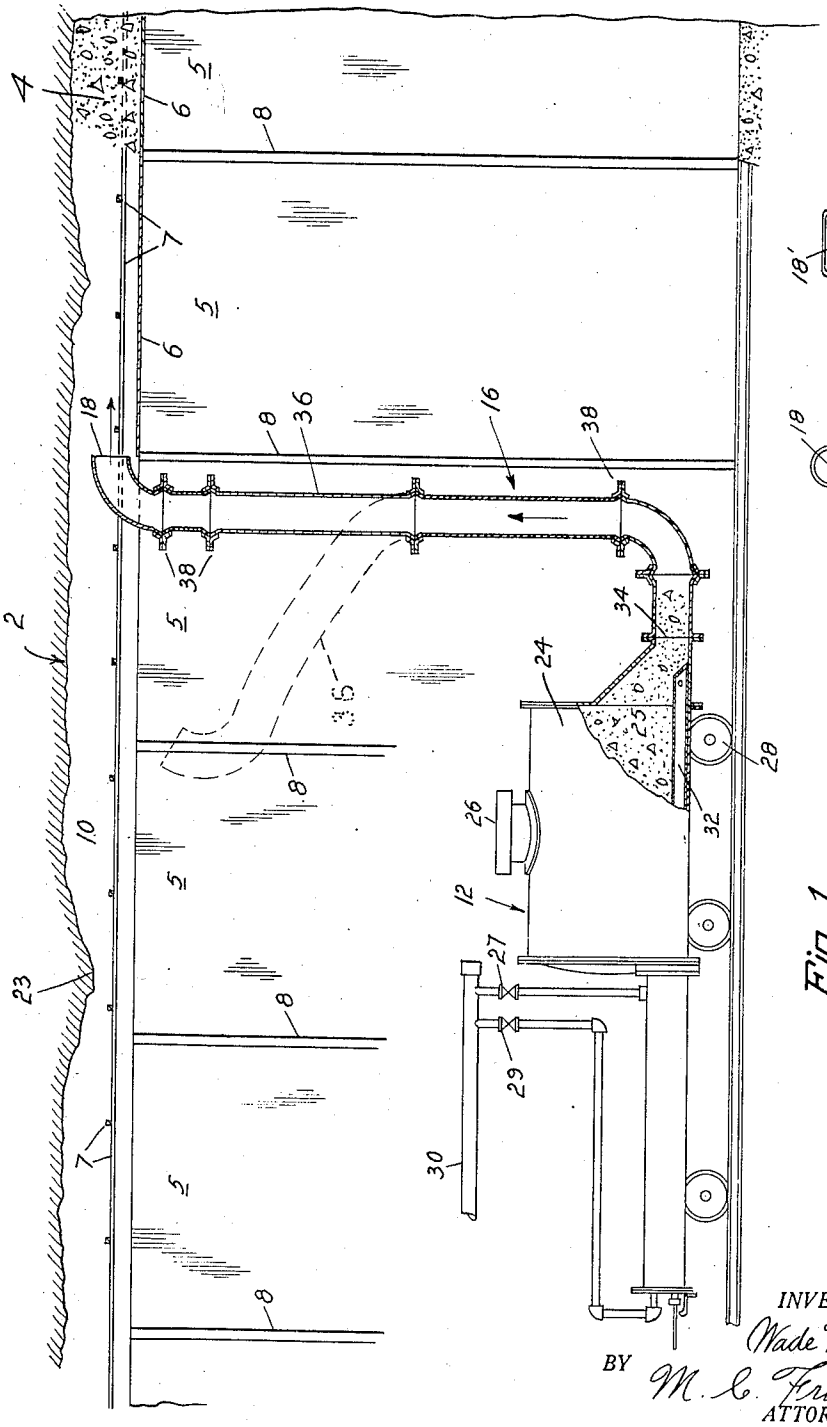


Fig. 1

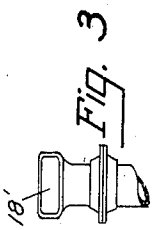


Fig. 3

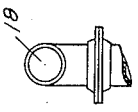


Fig. 2

INVENTOR.
Wade F. Webb
BY M. C. Frank
ATTORNEY

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UNITED STATES PATENT OFFICE

WADE F. WEBB, OF OAKLAND, CALIFORNIA

METHOD FOR APPLYING CONCRETE TO TUNNELS

Application filed September 21, 1926. Serial No. 136,847.

My invention relates to the art of lining tunnels such as are constructed for railroads, for hydroelectric power penstocks, and the like.

It has become the practice in large scale modern operations to line tunnels by shooting the concrete into place at high velocity. It has been customary to lay a long and expensive pipe line along the space between the forms and the original tunnel bore from the concrete gun to the point of concrete deposition, and to accurately coordinate the daily rate of construction of forms with the rate of deposition of concrete. If the forms were constructed too far in advance, an impracticably long pipe line was required; while a certain distance had to be maintained to insure against delay permitting the pipe line to clog with concrete. The use of a pipe line was deemed inherent in the pneumatic lining of tunnels because of the manner in which the forms must be constructed, and, due to the rigidity of the metal pipe line the concrete-placing machine could not be located within the forms and immediately adjacent to the section to be filled with concrete without great loss of time in adjusting the riser from the gun to the forms as the work progressed.

The laying of the pipe line is done after the forms are erected and the labor cost for laying is considerable. The original outlay for pipe and special couplings is a big item and the maintenance of the pipe line and couplings is expensive during the life of the job. The longer the pipe line, the greater the wear and tear on the pipe line, due to the increased velocity of the material as a higher pressure is built up in the pipe line; also the amount of air consumed in doing the work is greatly increased, thus necessitating very costly compressor installation.

In working with a long pipe line the danger of delays, due to clogging of the line, is very much greater than with a short pipe line, and the length of time required to locate and clean up a plug in the long pipe line is far in excess of that for a short line.

In teaching an improved method and apparatus for the lining of tunnels, it is the object of my invention: to avoid costly pipe line transmission of concrete: to avoid the laying of a pipe line and which omission permits a low air pressure to be effectively used as one step in the process of lining tunnels; to minimize the delay between concrete injection periods; to avoid the last-minute placing of reinforcing steel or closures to fill gaps left open for accommodation of tunnel-lining apparatus; to minimize the last-minute trimming of the original tunnel bore for removing rough spots; to generally increase the efficiency possible in tunnel lining; and to provide a method which is characterized by its high degree of flexibility and adaptability to the unforeseen situations which invariably are encountered in engineering work. It is moreover, the object of my invention to provide an apparatus having a high degree of flexibility; and to provide means for permitting control of the deposition of concrete to insure complete filling of the space between the original tunnel bore and the forms. Further and ancillary objects of my invention will become apparent upon the study of the specification and drawings accompanying and forming part of this application, and still further purposes will be suggested by the particular uses which the said invention may encounter.

Referring to the drawings:

Figure 1 is a vertical longitudinal section of a portion of a tunnel being lined, and illustrates the concrete gun in operative position immediately adjacent that portion of the tunnel to which the concrete is being placed.

Figs. 2 and 3 are end elevations of two types of nozzles supplied with the concrete gun.

In tunnel construction after forming the rough tunnel bore 2, a layer or lining of concrete 4 is applied. Wooden or steel forms 5, herein considered as sections of any suitable form, such as cylindrical for example, are supported by ribs 8 and are built within the tunnel; in the past, a pipe line was laid in the space 10, between the forms and the original tunnel bore and a gap was left in the upper portion of the forms 5, to be closed by key-plates 6, as successive pipe sections were removed. The pipe line will form no part of

my method but the key plates 6 will be used; the key plates being placed in position as heretofore, and as the work progresses and as the gun is moved to each successive position. Heretofore the concrete was forcefully ejected at high velocity, usually by compressed air, into the upper portion of the space 10 between the forms and the original tunnel bore. Due to its high velocity at ejection, the concrete packs itself into place, and, aided by gravity tends to flow to completely fill the space 10. Voids, however, often occur, and a means for minimizing them will subsequently be described. The air pressure requirements were costly, and the wear and tear of the pipe line very great due to the abrasive character of concrete and to the high velocity (approximately a mile a minute) of its transmission.

So far as I know, no satisfactory method has heretofore been proposed for overcoming the above-mentioned and other disadvantages in the existing method of lining tunnels. My improved method permits the pipe line itself to be dispensed with.

Instead of conveying the concrete through a long pipe line before its ejection, my method involves placing the concrete gun 12 immediately adjacent that portion of the tunnel to which the concrete is being applied. It will be understood that Fig. 1 represents just this small portion of a total tunnel which is actually undergoing concrete application at a given time. In order to obtain the desired proximity between the gun and the point of concrete deposition, it is to be assumed that the gun is positioned within the bore and encompassed by the forms 5. A flexible riser 16 leads from the gun, not to a pipe transmission line, but directly to the ejection nozzle 18 at the end of the riser.

In the working of my method, the forms 5 are fully constructed for any desired length of tunnel and need not necessarily be limited to the length of a single day's fill or by considerations of allowable pipe line length. The steps of building and of removing the pipe line are eliminated, and the steel reinforcement 7, if reinforcement is used, is completely placed in position in the lining space 10.

After the forms and reinforcement are completed, the gun with its nozzle in retracted position is rolled up to the point in the tunnel where the concrete is being applied, the nozzle inserted into the lining space at a key-panel entrance, the air pressure turned on, and the injection of concrete continued until the space 10 ahead of this entrance is filled with concrete. The nozzle is then retracted from the said space and a key panel 6 is placed, the gun is moved back to the next key-panel entrance, and injection is immediately recommenced from this point. The time consumed for the shift is negligible.

As compared to the one hundred pounds per square inch pressure customarily required to operate the concrete gun in lining tunnels, I find forty pounds per square inch sufficient in my improved method. The saving in air cost is greater than the ratio of one hundred to forty.

The apparatus required for my improved method is so inexpensive and so easily transportable that it is found practicable to use the pneumatic method of concrete application in the construction of tunnels which are too short to justify the use of the older method and which therefore up to the present time have been lined by hand.

The form of apparatus I have found most advantageous to the accomplishment of my method consists of a concrete gun 12 connected by a short flexible conduit 16 to its ejection nozzle 18. The concrete gun is a closed container 24, having an opening into which the concrete 25 is periodically dumped, and a hermetic closure 26 for this opening. The gun may be mounted on trucks 28. A source 30, of compressed air, controlled by valves 27 and 29 is provided for ejecting the concrete. The compressed air is discharged into and behind the mass of concrete within the gun, through a movable pipe 32, all of which is described in detail in my copending application Serial Number 136,848, filed Sept. 21, 1926. The compressed air forcibly ejects the concrete through the opening 34, flexible conduit 16 and directly out of the nozzle 18.

The flexible conduit permits the nozzle to be retracted when shifting the gun within the tunnel, and also allows the nozzle to be aimed so that the stream of concrete may be directed in any direction to fill voids or to completely fill around such obstacles as the reinforcing steel, or rock projections 23 from the rough surface of the original bore. In preferred form the flexible conduit is fabricated of a section 36 of reinforced rubber pipe, and has one or more suitable swivel couplings, universal joints 38 or the like, interposed between the gun and nozzle. In Fig. 1 the dash lines indicate a retracted position of the nozzle.

In positions such as that indicated at 23, where a rock projection juts from the roof of the tunnel, it has been customary to chip the tunnel and the forms to make room for the injection apparatus. In order to avoid any necessity for such cutting, with my new method and apparatus, the attachment shown in Fig. 3 is provided. It consists of an oblong sectioned nozzle 18′ adapted to be substituted for the circular nozzle 18 (see Fig. 2) when points of low roof clearance would prevent use of the latter. As shown in Figs.

2 and 3, the cross-sectional area of the two nozzles is substantially the same.

In operating the gun, periodic refilling with concrete is necessary. The concrete supplying mixer may in some cases be operated within the tunnel immediately adjacent the gun, or in other cases a skip or other conveyor may be used to transport the concrete to the gun. In fact, the portable gun itself can be used as a conveyor.

My method is an improvement calculated to overcome the several disadvantages of methods of tunnel lining formerly known, and certain of its advantages may be realized with the practice of less than all the preferred steps set forth in the specification. Obviously, modifications of the apparatus herein described in detail are also possible within the purview of my invention. Therefore I wish not to be limited to an interpretation narrower than that set forth in the claim.

I claim:

The method of lining tunnels which comprises erecting forms in the tunnel bore leaving the key panels therefor out of position, placing a single key panel in position, transporting concrete to a point within said bore adjacent the termination of said forms, ejecting said concrete at comparatively low velocity into the space between said key panel and said bore at the front thereof and allowing said concrete to flow about said forms until the entire space between the forms and the key panel and the bore is filled, then moving said concrete backwardly, placing another key panel in position and repeating the operation of filling the space between the forms and bore with concrete from the front of said last mentioned key panel.

In testimony whereof, I affix my signature.

WADE F. WEBB.