No. 714,204. Patented Nov. 25, 1902.

G. LINDENTHAL.

TUNNEL CONSTRUCTION.

(Application filed Jan. 24, 1902.)

(No Model.) 2 Sheets—Sheet 1.

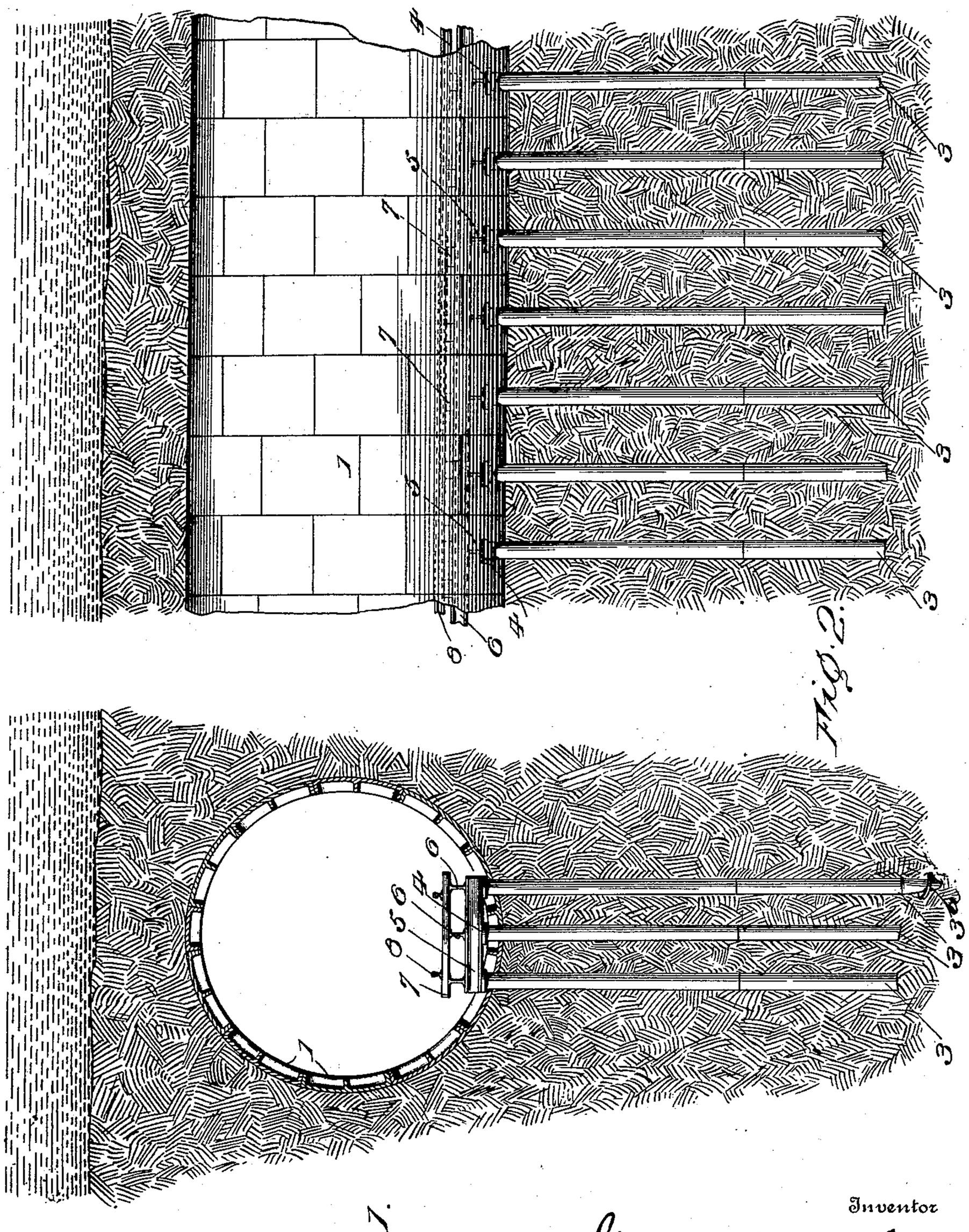


Fig. 2.

Fig. 1.

Witnesses

Jno. Innis
Jas. Stewart Rice.

Inventor

Gustav Lindenthal

By

Thos. E. Robertson Attorney

No. 714,204. Patented Nov. 25, 1902.

G. LINDENTHAL.

TUNNEL CONSTRUCTION.

(Application filed Jan. 24, 1902.)

(No Model.) 2 Sheets—Sheet 2.

Fig. 4.

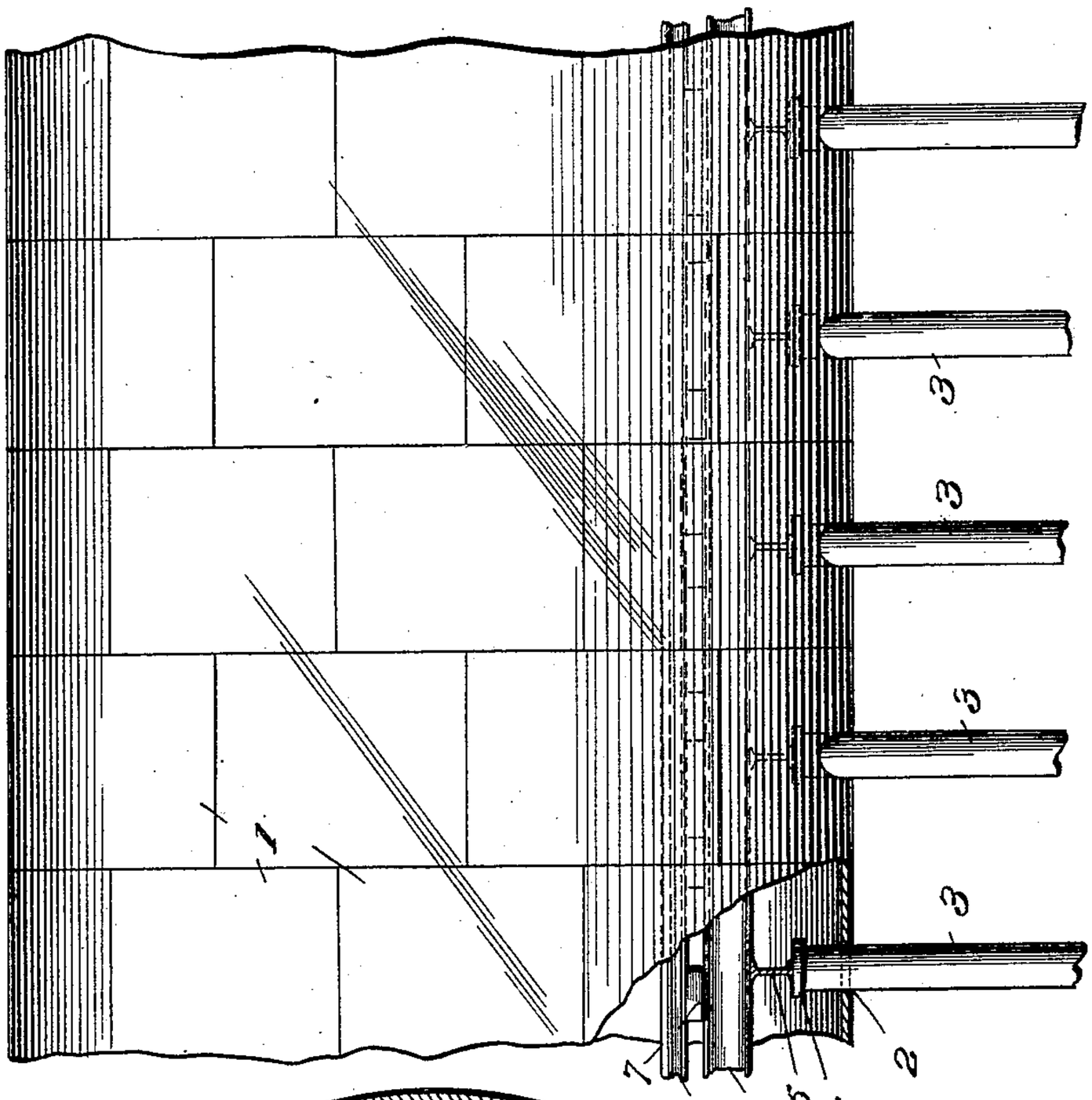
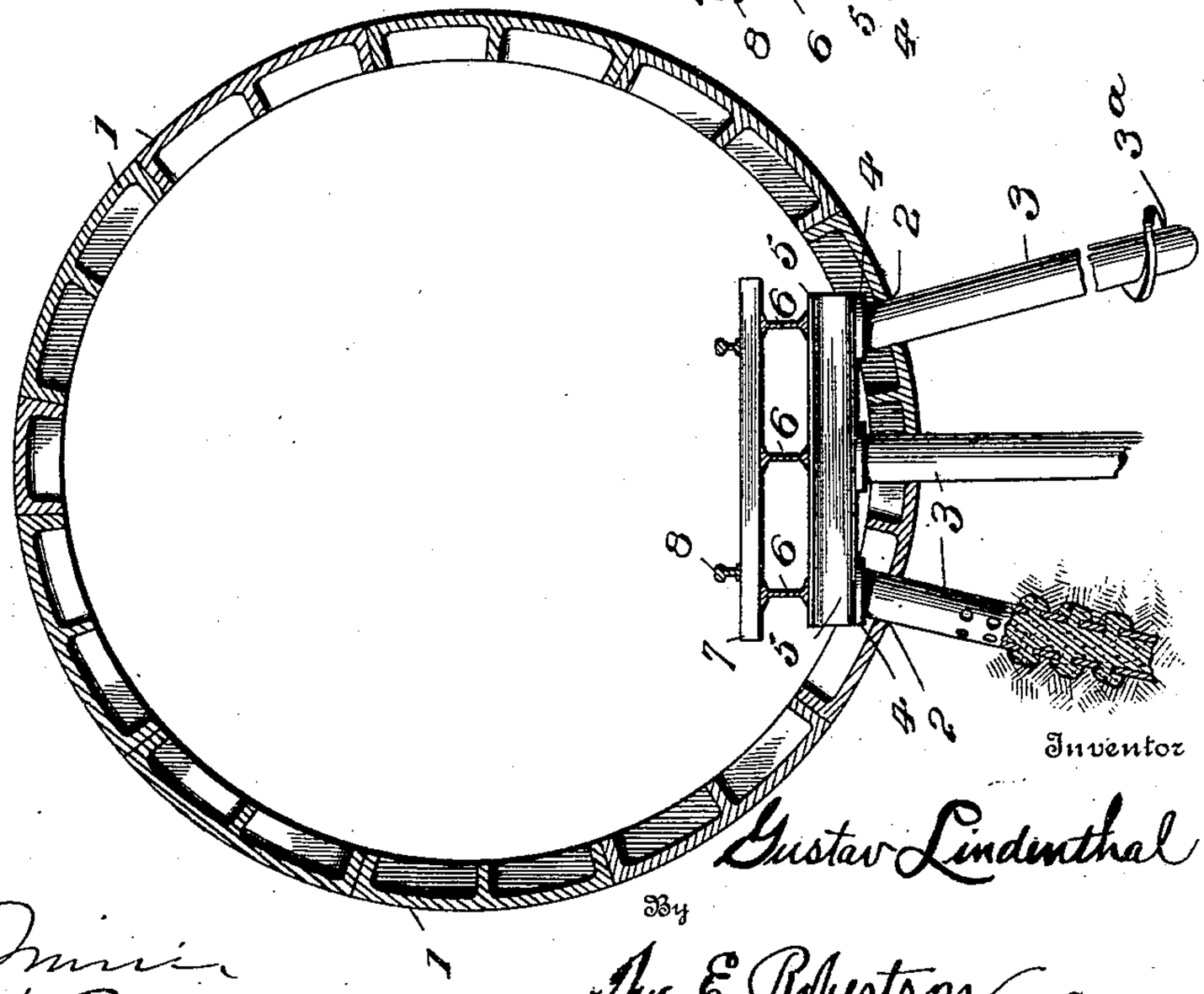


Fig. 3.



Witnesses

J. Stewart Price.

Inventor

Gustav Lindenthal

By

Jas. E. Robertson Attorney

UNITED STATES PATENT OFFICE.

GUSTAV LINDENTHAL, OF NEW YORK, N. Y.

TUNNEL CONSTRUCTION.

SPECIFICATION forming part of Letters Patent No. 714,204, dated November 25, 1902.

Application filed January 24, 1902. Serial No. 91,106. (No model.)

To all whom it may concern:

Be it known that I, GUSTAV LINDENTHAL, a citizen of the United States of America, and a resident of New York, in the county of New York and State of New York, have invented certain new and useful Improvements in Tunnel Construction, of which the following is a specification.

This invention relates to improvements in submarine or subaqueous tunnels, and more particularly to that class of tunnels in which a tubular metallic shell forms the casing of the tunnel; but the invention may be capable of use in tunnels of other forms.

The object of the invention is to provide a tunnel which can be built through a soft foundation without the sagging, which usually results from the weight of concentrated loads passing through the tunnels.

My tunnel in its preferable embodiment is formed of cast-iron segments joined in the usual manner and after being driven through the bottom below the water with the aid of the ordinary "shields" has a suitable number of piles sunk into the soil under it, the piles being preferably of tubular form and forced through suitable openings left or formed in the skin or casing of the tunnel. I prefer to drive these piles so as to form a regular continuous pile formation under the tunnel rather than in the form of piers and to drive them from within the tunnel, so that the load may be partially or entirely supported by the said piles.

With the aforesaid object in view my invention consists in the tunnel, as will be hereinafter more particularly described and then set forth by the claims at the end hereof.

In the drawings which accompany and form part of this application and which represent the preferable form of my invention, Figure 1 is a view of a portion of a river-bottom, showing my invention in vertical section. Fig. 2 is a side elevation of the tunnel and pile formation shown at right angles to that shown in Fig. 1. Fig. 3 is a cross-section, on a much larger scale, of a tunnel with my improvement thereon; and Fig. 4 is a side elevation of the same.

Referring now to the details of the drawings by numerals, 1 represents a series of metallic segments which are joined to form the skin or casing of the tunnel. The tunnel is driven through the river-bottom below the water with compressed air, using any of the well-known shields or any other suitable apparatus. The operation of these shields is so familiar that it is unnecessary to describe it here further than to state that the tunnel is built on in rings section after section as the shield, with its telescopic tube, is driven forward by means of hydraulic jacks or any other convenient means. It has been heretofore proposed to build tunnels of this character; but when they are built through a soft foundation they are apt to sag under the weight of the concentrated loads which pass through the tunnels when the latter are used for railways, and this sagging necessarily causes the joints of the tunnel to open and leak, allowing water to enter the joints, which of course must be avoided. The means which I use to prevent this sagging will now be described. Through suitable openings 2, left or formed in the bottom segmental plates, I sink hollow iron piles 3. These piles, which may be of a length shorter than the diameter of tunnel, are inserted through the aforesaid holes 2 from the inside of the tunnel. By the application of a water-jet in the usual way through a pipe centrally inserted and by the use of hydraulic or other jacks resting on the tops of the piles and exerting pressure against the top of the tunnel the piles may be forced down to the desired depth. Instead of the hollow piles herein described I use the well-known screw-piles, (see 3^a in Figs. 1 and 3,) which are driven by turning and screwing the piles down into the soft material.

The piles may be spaced as closely as needed, both lengthwise and crosswise of the tunnel; but I prefer that they should be closely driven into the soft river-bottom in the form of a regular continuous pile formation, and while I have represented them as being perpendicular to the axis of the tunnel in Figs. 1 and 2 they may be driven so as to diverge, as shown in Fig. 3. I therefore wish it to be distinctly understood that my invention is not to be limited to the manner in which the piles are spaced, as the spacing will be determined by the character of the river-bottom and by the loads which the pile formation will be likely to carry.

After the piles have been driven in position the joints between them and the bottom section of the tunnel may be made water-tight by calking or in any suitable way to prevent the intrusion of water through the openings; but as the method of calking forms no part of my present invention it is unnecessary to further mention it.

When the piles 3 are in the positions determined upon, the top of each one is sawed or dressed off by suitable tools and adjusted to a level and caps 4 (preferably formed of cast-iron) are fastened to them in any desired manner. On the tops of these caps are secured iron beams 5, which are disposed crosswise of the tunnel, as clearly shown in Fig. 3, and these beams 5 in turn have secured to them, by riveting or otherwise, a series of longitudinal I-beams 6, which form a firm foundation for the tie 7, upon which rests the rails 8. This is one of the constructions which I prefer to use when the tunnel is intended for railway purposes; but other constructions for the support of the rails may be adapted to the piles. If the tunnel is used for other purposes, the tops of the iron piles are leveled off and may support a cement or asphalt concrete or other roadway to present a suitable surface for the road traffic.

The length of the piles will of course depend to some extent upon the nature of the soil through which the tunnel passes, and while I have hereinbefore stated that the piles are of a length somewhat shorter than the diameter of the tunnel I have shown them in some of the figures as being of much greater length. Of course when the piles are of greater length than the diameter of the tunnel they must be spliced. The splicing may be done in any of the usual ways and the spliced piles sunk with the water-jet in the usual manner.

In some instances I prefer to use piles like those illustrated at the left-hand side of Fig. 3, in which a hollow pile is shown with a number of lateral holes in its sides. These piles are filled with cement, concrete, or other suitable material, which oozes out into the material surrounding the piles, and thus increases its frictional resistance and bearing capacity.

From the foregoing description and accompanying drawings it will be seen that I have invented a pile formation which provides a reliable support for a railway or road-bed, and as the piles are driven from the interior of the tunnel the driving may be done under the protection of the sections of the tunnel. Furthermore, as the piles are shown in my drawings the load is supported directly by them and the tunnel itself does not have to support the load, but merely acts as a water-tight inclosure for the same.

I am aware that it is a very common engineering practice to sink piles for a foundation for a tunnel to rest upon, and hence do not attempt to claim this broadly. I am also familiar with United States Patent No. 101,174 to Spear, granted over thirty years ago, and was familiar with it before I filed my application; but I regard my invention as essentially different therefrom, as Spear's idea was to float a "tunnel or other marine work" to its destination, sink it to place, and "anchor" or "fasten" it by "spikes" or "screws," and these spikes or screws were not intended to support or assist in supporting the load or the roadway carrying the load, but merely to anchor the tunnel and overcome any tendency to float. My invention is radically different from this, as it involves an outer casing or shell for protecting a roadway and means for directly supporting or assisting in supporting the load or the roadway carrying the load. Therefore no claim is made herein to a tunnel which is provided with spikes or screws which do not form a support or partial support for the load, as I regard it as very important that the piles or other means shall carry or partially support the load or the roadway, as by this construction the tunnel itself does not have to entirely support the load, as in Spear's patent, but merely acts as a water-tight inclosure for the same, as set forth in the preceding paragraph. I believe I am the first to invent a tunnel where the load (which is inclosed within a shell or casing) is borne or even partially supported directly by piles, which pass into the material beneath the inclosing casing of the tunnel. I intend to cover this feature broadly, and therefore changes may be made without departing from the spirit of my invention. For example, I have referred to the use of hollow iron piles and screw-piles; but it is obvious that in some cases wooden piles may be substituted. This and other changes may be made without departing from the lines of my invention.

What I claim as new is—

1. A tunnel comprising an inclosing casing and means for directly supporting the load or roadway, said means comprising piles passing into the material beneath the said inclosing casing, substantially as described.

2. A tunnel comprising a water-tight inclosing casing, a roadway therein, and piles directly supporting said roadway, said piles passing into the material beneath the inclosing casing, substantially as described.

3. A tunnel comprising an inclosing casing, a roadway within the same, and piles on which said roadway is directly supported, said piles projecting through the tunnel-casing into the material beneath said casing, substantially as described.

4. A tunnel, a roadway therethrough, a continuous pile foundation for supporting or partially supporting directly the said roadway, substantially as described.

5. A tunnel comprising an inclosing casing and having as a foundation piles which have their ends protruding through said casing, and a roadway resting directly on said piles, substantially as described.

6. A tunnel-foundation comprising a number of piles having their upper ends protruding through the casing of the tunnel and carrying the load thereon, substantially as described.

7. A tunnel-foundation comprising a number of hollow metallic piles having their upper ends protruding through the casing of the tunnel and supporting or partially supporting the load, the said hollow piles having a series of lateral passages leading from its center, and a binding material inserted in said hollow piles and projecting through the lateral openings and increasing the frictional resistance and bearing capacity of the pile, substantially as described.

8. A tunnel comprising a casing, a foundation therefor consisting of piles having their upper ends inserted in openings in said casing, and a road supported on said upper ends, substantially as described.

9. A tunnel comprising a casing and a foundation therefor consisting of piles having their upper ends inserted through openings in said casing, beams supported within the casing upon said upper ends, and rails supported by said beams, substantially as described.

10. A tunnel comprising a casing and a foundation therefor consisting of piles having their upper ends protruding within said casing, caps for said upper ends, transverse beams resting upon said caps, longitudinal beams resting upon said transverse beams, and rails supported by said beams, substantially as described.

Signed by me at 45 Cedar street, New York, this 22d day of January, 1902.

GUSTAV LINDENTHAL.

Witnesses:
M. B. SANFORD,
C. V. HOWARD.