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2,057,524

WALL CONSTRUCTION FOR TUNNELS, SHAFTS, AND PIPE

Filed Sept. 22, 1934

2 Sheets-Sheet 1

Fig. 1.

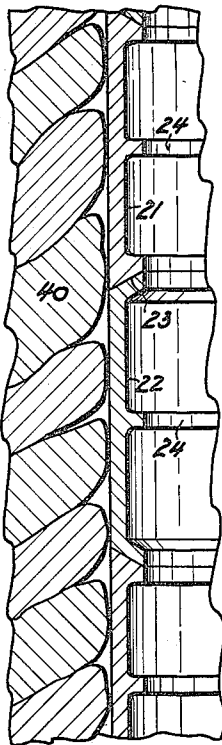


Fig. 3.

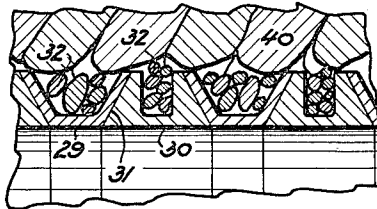


Fig. 4.

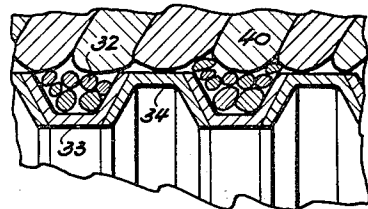


Fig. 5.

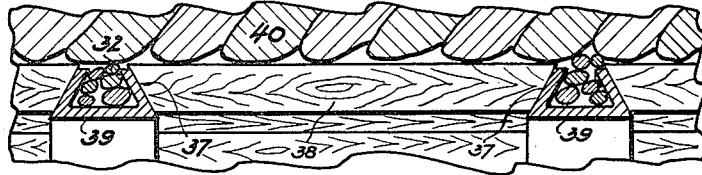


Fig. 6.

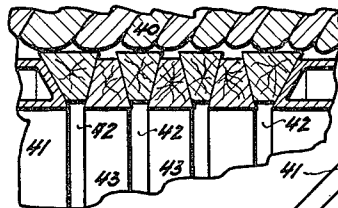


Fig. 7.

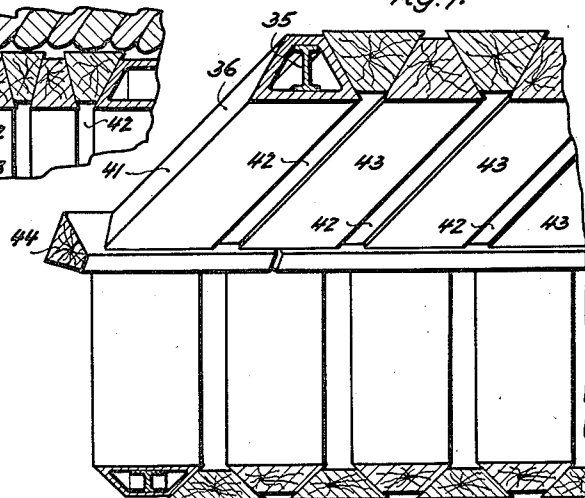


Fig. 2.

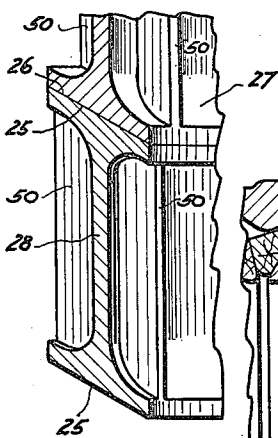
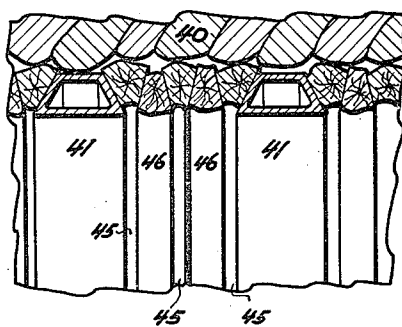


Fig. 8.



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2 Sheets-Sheet 2

Fig. 9.

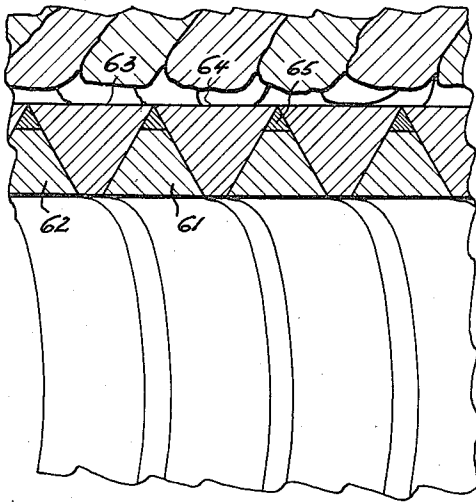


Fig. 10.

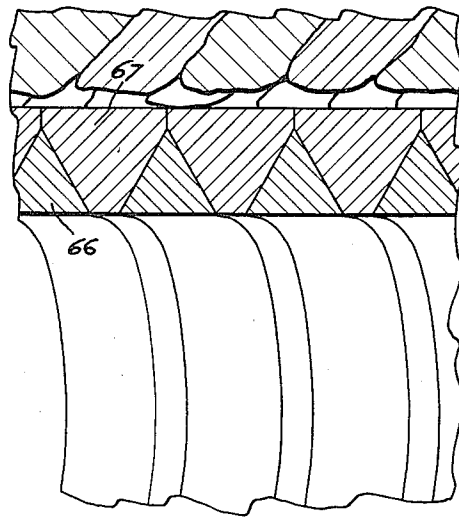
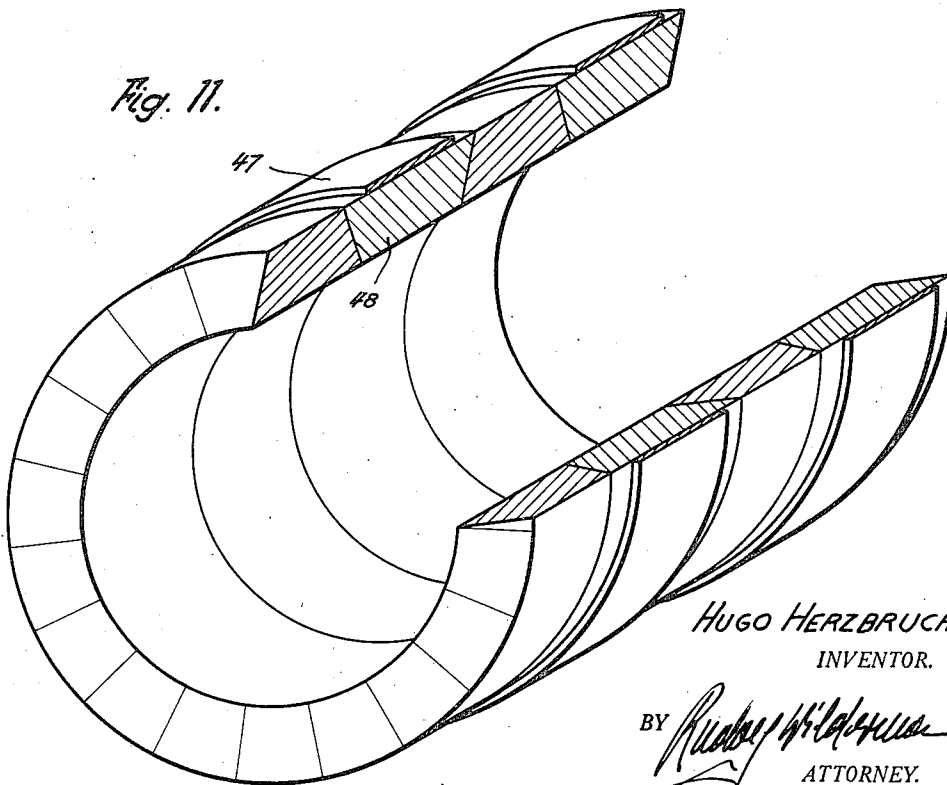


Fig. 11.



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UNITED STATES PATENT OFFICE

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WALL CONSTRUCTION FOR TUNNELS,
SHAFTS, AND PIPE

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5 Claims. (Cl. 61—42)

This invention relates to the construction of the walls of tubes such as tunnels, shafts, pipes, etc., and more particularly it is directed to a method of and means for binding upon each other and interconnecting successive sections which those structures are composed of.

Such sections may be assembled as masonry to form an arch or of segments of concrete or reinforced concrete or they are executed to structural metal forms, rings, tubing, etc., and serve to line a passage outwardly when it passes through the ground or serve to form an enclosure when the structure is a conduit.

When the sections of such a structure are arranged side by side and lack strong jointing means, they may gape or shift apart transversely, as it would for instance occur, when in a tunnel passing through a rock formation an excessive pressure is exerted by the rock upon one side. Even small cracks or fissures caused in that manner allow water to leak into the passage and, vice versa, water and air may enter upon the surrounding dry rock and are the indirect cause of disturbance.

I have invented a method interlocking the successive sections surrounding a passage by conferring upon the sections a wedge shape, each section being inwardly or outwardly uniformly attenuated.

The inclined surfaces of contiguous sections rest upon each other, providing that successive sections are alternately attenuated inwardly and outwardly respectively, at substantially like angles.

If the arches or rings of such sections yield under an exteriorly applied pressure, then the wedges are forced between each other at the point of yielding; thus a reaction is set up which prohibits further yielding, and the interlocking of adjoining sections is increased. This effect is obtained, even when the pressure acts only upon a ring which is outwardly attenuated, since under those circumstances the wedge shaped parts of such a ring are forced, at other points, to enter between inwardly attenuated or tapered rings and under the resultant reaction gaping is avoided at the point where the pressure was originally applied. A lining of this kind is extremely durable, has a great resistance to all kinds of influence, and is waterproof once for all.

It is an object of this invention also to apply the principle of overlapping the wedge shaped sections of a passage in the case of conduits, which are subjected to a particular inside pressure, subterranean passages for instance, which

are to be protected against explosions, or water pipes in connection with dams.

In the case of passages which are to withstand a pressure from the outside, the inwardly tapered rings enter upon the interposed rings in such manner, as to produce a reactionary wedge action, due to which the pressure is evenly distributed between both kinds of rings. This result is enhanced in proportion to the increase of the exterior pressure.

In order to introduce such reactions in the case of conduits exposed to an interior pressure, the wedging component of force must be applied from the outside. For that reason an exterior pressure is provided for and is particularly applied to rings which are inwardly tapered. Since, in the case where we thus set up an outside pressure by collateral means, such outside pressure may be controlled and regulated, the even distribution of the resultant pressure conditions is subject to full control.

The principle of interlocking successive sections surrounding a passage in wedge fashion may be supplemented by overlapping the segments forming each section in a peripheral direction. In such an instance the adjoining segments are joined together in planes substantially passing through the imaginary center of the passage. This is of great value in the case of concrete segments.

I have the further object to extend the principle of this invention to a mode of construction in which the enclosure or lining is made of structural iron. Structural iron has great economical advantage over concrete in the construction of the walls of conduits and in lining passages, for the following reasons:

When steel or structural iron are used, the thickness of the walls may be considerably reduced on account of the greater strength of such material. This yields the additional advantage that during the progress of reinforcing or lining a passage the work may be greatly expedited when a metal construction is used and collapsing or caving in of the unarmored parts may be forestalled by the use of the thinner metal armoring because it requires less space and therefore less excavation and it is more quickly installed.

A third important advantage of using steel or iron for lining a passage,—as compared with the use of concrete,—is the relative immunity of such structure against chemical reactions which might be set up by the infiltration of fluids. It is well known that it is difficult to protect a concrete

lining against corrosion and erosion under such influences.

A further object of this invention is to provide for a manifold mode of construction in which various materials are alternately used. Thus I provide for the alternative use of timber or steel or for an assembly combining longitudinal members, with others extending peripherally around the passage.

A further object of this invention provides for waterproofing in connection with the wedge-fashioned interlocking method of this invention. I make provision to have water-proof material forced into all crevices or seams of the sections assembled by way of my novel type of construction as a result of the particular wedge action exerted by sections and segments upon each other.

These and other objects of my invention will be brought forth in, and better understood from the following description of my invention and the exemplary illustrations of the accompanying drawings, in which:—

Fig. 1 shows a cross-section through the wall of my construction adjoining a rock in formation; tubing of a preferred cross-section is used.

Fig. 2 shows in a cross-section a modification of the tubing.

Figs. 3 and 4 show cross-sections of lining made of U-shaped tubing.

Fig. 5 shows the cross-sectioned structure of a wall in which timber is longitudinally interposed between metal sections surrounding the passage.

Fig. 6 shows the cross-section of a wall in which the metal and timber sections extend in alignment.

Fig. 7 shows in a cross-section longitudinal and transverse timber and metal sections assembled to form a polygonal lining or enclosure.

The cross-section of Fig. 8 shows a similar construction in which the natural convexity of the timber is made use of.

Fig. 9 shows the view of a wall section in which a water-proofing plastic is involved.

Fig. 10 shows in a similar view, a preferred arrangement in which the outwardly tapered rings are not exposed upon the outside of the wall.

Fig. 11 shows in a partly sectioned view the use of exterior banding for the purpose of applying controlled pressure to the inwardly tapered sections of a wall.

Like numerals refer to similar parts throughout the various views.

Whereas the prior art showed the abutting faces on tubing, which forms sections of a lining of a conduit, to be parallel to each other, I arrange the faces of tubing, which abut upon adjoining tubing, to be disposed at an incline to each other,—the tubing is shaped trapezoidally, so to speak,—and the abutting faces of the adjoining tubings are correspondingly inclined. In this manner one tubing 21 has side faces which are inwardly tapered or attenuated whereas the corresponding faces of the adjoining tubings 22 are outwardly tapered or attenuated. In like manner other tubings are alternately wedge-shaped inwardly or outwardly as it is shown in Fig. 1.

In Fig. 1 the wedge action between adjoining tubings 21 and 22 takes place at the inclined face 23 and the tubings are reinforced by exemplarily indicated webs 24.

The tapering of the sides of the tubing along the outline of a trapezoid may be replaced by inclined faces arranged in the manner of a parallelogram; thus the inclined side faces 25 and 26 of tubing 27 of Fig. 2 are parallel to each other.

Fig. 2 shows a modification of the construction inasmuch as the inclined end faces extend outwardly as well as inwardly from the connecting rib 28. Thus the wedge faces of tubings, whether they have the trapezoidal outline of Fig. 1 or the outline of the parallelogram as shown in Fig. 2, may be extended ad libitum, and the lining or conduit is reinforced at the most exposed and dangerous point, i. e. where the tubings rest upon each other. The parallel formation will only be used in specific cases of subsectioning, but generally the modification of Fig. 2 will also be executed in trapezoidal outline. The wedge faces at opposite ends of a tubing may be reinforced in relation to the connecting rib 28 and/or to each other, e. g. by web 50.

Engaging adjoining tubings of old systems upon each other by means of bolts was insufficient and frequently endangered operation. Thus the bolts were frequently sheared off and the tubings were laterally displaced in respect to each other. In my system of lateral support and of wedging the tubings upon each other, the danger of radial displacement is substantially avoided since the inclined faces serve to preserve alignment. When the edges of the tubings are reinforced and the wedge shaped side faces are suitably extended, the use of bolts for joining together adjacent tubings may be dispensed with altogether. Even though there might be an increase in material due to such extension of the abutting faces, an economical disadvantage due to such an arrangement is completely offset by the gain which is brought about because bolts do not have to be used any more and their cost and the cost of the bolting operation are dispensed with.

For that reason tubing of this kind may be installed at a great saving of time and the binding of adjacent tubing upon each other represents a great improvement when compared with the old art; the structure is protected against dislocation of sections in every respect.

A still stronger armored lining for a passage is provided by the arrangement of Fig. 3 in which the trough-shaped sections 29 and 30 are open outwardly and again are bound upon each other at the inclined faces 31. The rock 32 may be filled in and bound by cement upon the outside of either kind of tubing and serves to weigh and anchor the lining.

Fig. 4 shows a further modification in which the trough shaped sections 33 and 34 are open outwardly and inwardly, respectively, so that they are of substantially like cross-section. The outer groove of the inwardly attenuated section 33 may be reinforced, anchored and weighted by rock or concrete 32 so that a binding action upon the surrounding rock in formation is enhanced, that the inwardly attenuated sections may withstand pressure applied from the outside, and that the concrete filling binds these sections in a way similar to that indicated in Fig. 11. A hollow structure or material which is surrounded in truly trapezoidal fashion by a wall such as indicated in Figs. 6 and 8 may be substituted for the structural forms of Figs. 3 and 4 and a reinforcing beam may be used in connection with the outwardly attenuated sections as indicated by beam 35 in the hollow structural member 36 of Fig. 7.

I also have extended the principle of my invention to a more economical arrangement, in which the radial and axial wedging is preserved in the same manner as illustrated before, but in

which the metal beams are partially replaced by timber. An iron-timber construction has been known in the art of mining before. Iron supports were arranged at predetermined distances in the shape of rings, frames, polygons, etc., longitudinally disposed timber or bars rested upon the outside of the iron supports and were therefore exposed exclusively to a particularly strong bending stress. A collapse of the timber was frequently followed by a cave-in of the rock.

In accordance with the present invention I use iron supports which are arranged uninterruptedly or in segments in the shape of rings or polygons all of which have a cross-section which is outwardly wedgedly attenuated. Where rings are used the same structural forms of sections or tubing which were described above in the case of walls executed completely in iron. Under this mode of construction the timber may be arranged generally as it was applied in the old art, i. e., normally to the iron sections. But the timber is slanted at both ends, the slanted ends being inclined towards each other, and the inclined sides also face the inside of the passage. These slanted ends 37 of the longitudinally disposed timber 38 rest upon the oppositely inclined faces of the tubings 39. The shape of the tubing again offers a convenient means to reinforce and bind it by a filling 32 and to anchor it upon the surrounding rock 40 (Fig. 5).

While a construction of this kind immediately offers the advantages of my axial wedging, the advantage may be enhanced by suitably shaping the timber along its longitudinal sides in wedge or peg fashion so that we obtain a trapezoidal or triangular cross-section. The inclined faces of the sides of the timber rest upon each other, in arch fashion.

But it is also possible to arrange the timber in a different manner, i. e., in an opposite direction; that has not been known heretofore. In that instance it is not disposed normally to the intermediate iron supports, but it is extended in parallelism thereto. In this instance the timber is shaped in accordance with the principle of my invention, i. e., the side faces are wedgedly disposed and alternately attenuated or tapered towards the outside of the passage and towards the inside thereof, respectively. This is illustrated by Fig. 6 in which 41 are the spacedly arranged iron supports, 42 are the inwardly tapered pieces of lumber and 43 are the outwardly attenuated or tapered wooden beams.

In executing this mode of construction axially extended timber 44 is arranged at the corners of the polygonally shaped lining or conduit and serves to anchor the ends of the iron beams as well as of the wooden beams extending parallel to the iron beams (Fig. 7).

It is distinctly understood that the timber will not have to be squared up and finished on all sides for the purpose of conversion under my principle, but it is necessary to provide the inclined faces upon the sides as shown in Fig. 8. In this case the beams 45 have the inwardly gathered sides whereas the intermediate beams 46 are tapered outwardly.

Where I use timber under the principle of my invention, stresses are applied thereto which comprise pressure and bending components, by way of contrast with all prior modes of construction in which the timber was exposed to bending stress exclusively. Here the use of timber is therefore not limited to the protection of a passage against falling rock, in which instance it merely serves as

a partition, but it forms a part of the vault, lining or conduit and is rigidly bound into the whole structure. Therefore this represents the first instance in which timber is used to the fullest extent. Could a metal-lumber construction be used heretofore only in instances where there was no pressure or very little pressure exerted by the surrounding rock,—although such type of construction was much preferred from an economical aspect,—this invention makes it also possible to apply a combined metal-wood construction in instances where there is a great pressure on the part of the surrounding rock; the use of round timber, which is flattened on the abutting tapered sides only, enhances the economical advantage of such construction.

It is well understood that the intermediate supports, which hereinabove have been described as iron or metal supports only, may also be executed in reinforced concrete.

It has been noticed in illustrations hereinabove described that the inwardly tapered sections offer a greater outer surface than the sections therebetween. In many instances the inwardly tapered sections extend outwardly beyond the circumference of the outwardly tapered sections. Thus, the inwardly tapered sections are primarily exposed to the pressure applied from the outside and the outwardly tapered sections are but indirectly exposed to the outwardly applied stress, i. e., by way of the intermediate inwardly tapered sections. Thus the wedging action is greatly enhanced and not only is gaping prevented but the abutting sides are continually pressed into abutment and as a result a tight enclosure is provided for.

This action, under which the adjoining sections are tightly bound upon each other for reasons of the pressure applied from the outside upon the inwardly tapered sections, may be specifically created by providing outwardly disposed pressure and binding means, where a pressure from the outside is lacking. Particularly in the instance where we have segments of tubing or reinforced concrete or where we have a masonry arch construction, a more or less broad annular member,—with ends adjustably locked together or in the shape of an endless hoop,—may be extended over the outside of the inwardly tapered sections. Such an annular member is shown at 47 in Fig. 11 where it is applied around the stones forming the inwardly tapered sections 48. The annular member may be applied during or after construction, and it may be heated while being applied, by an electric resistance heating method, for instance, when shrinking, such an annular member, ring or hoop, will compress the section to which it is applied and the pressure exerted thereby may be previously determined and the ring member may be dimensioned accordingly. Of course I do not claim here the advantage of shrinking a compression member around a compressed member generally, but such action is novel in connection with an arc which is composed of wedge-shaped segments, a complete section being again bound upon adjoining sections owing to the incline of the abutting faces.

The results obtained by the use of a ring member extended around the outside of sections may be enhanced, or the heating or shrinking effect may be replaced, by the use of means,—in joining together the segments,—which expand while settling. Cementitious compounds adapted for such purpose are well known in the art. The

compression exerted by the encircling members is not taken up solely by the section to which such a member is actually applied but it is propagated to and taken up by the intermediate sections and a fully balanced pressure effect may be attained in conduits where an internal pressure medium, such as water, is applied.

It will be readily understood that with this type of construction enclosures which are relatively thin may be used and my novel construction is therefore particularly economical in executing a structure of this type in masonry. It is of course understood that in the case of the alternate inwardly attenuated sections, the individual stones or segments have the shape of truncated pyramids, whereas the members making up the remaining sections are outwardly attenuated in the longitudinal direction of the passage whereas they are inwardly attenuated in a peripheral direction.

In these specific cases as well as in all cases of general application of my invention, the outwardly attenuated sections may not only be set back from the outer surface of the lining or wall as it was described in various instances before, but they may be dimensioned relatively to the intermediate, inwardly attenuated or tapered sections in such a manner that they do not show on the outer surface at all and are therefore never directly subjected to any exteriorly applied pressure. Such applications of my invention are particularly illustrated in Figs. 9 and 10. While both types of sections making up the wall shown in Fig. 9 are trapezoidal in cross-section, the average diameter of the outwardly attenuated sections 61 is smaller than that of the inwardly attenuated sections 62 so that the outwardly attenuated sections are not seen at all but that the inwardly attenuated sections form longitudinally the continuous outer surface 63 of the wall. But they touch each other merely at the ends of the bases 64 of their trapezoidal cross-sections.

Where the said inwardly attenuated sections touch upon each other there is a clearance between said sections extending down to the narrow outer side of the outwardly attenuating sections. This hollow space 65 may be filled with a plastic material, asphalt for instance, which makes the structure water-proof. Thus penetration of water from the outside is prevented and the abutting surface of the sections are likewise protected against infiltration from the outside.

In the modification of Fig. 10, the outward sections 66 are triangular in cross-section and the outward extension of the inwardly attenuated sections 67 has still been carried further. In this instance the trapezoidal sections with the inwardly attenuated cross-section are flattened off at both sides so that such alternate sections abut upon each other in planes normal to the extent of the passage. In this manner the outward strength of the construction becomes greater and the triangular cross-sections of course again may be replaced by trapezoidal cross-sections,

thus providing a space for plastic waterproofing material or another suitable filler.

A wall of my construction may be outwardly lined and bound upon the surrounding rock by a forcing or expanding cementitious material of the kind referred to above so that the necessary reaction is provided for when particular pressures are applied to the walls and passage from the inside, by water for instance.

The stone used in my construction may be made of different materials. It may be composed for instance of concrete, brick, clay, slag, etc. My system is particularly adapted for an economical lining replacing the old brick wall enclosure of conduits. The use of cement as a binding material can be limited to the seams, between the stones of each section; but for the seams between the outer and inner wall or mantle and between adjacent sections, i. e., in an axial and radial direction the interlocking of the stone provides a sufficient binding.

Although I have shown and described one form of embodiment of my invention in detail, yet I do not wish to be limited thereby, except as the state of the art and the appended claims may require, for it is obvious that various modifications and changes may be made in the form of embodiment of my invention, without departing from the spirit and scope thereof.

What I claim is:

1. A tube comprising sections conically overlapping each other at abutting, inclined faces, one of said sections extending in wedge-fashion in between others, and a pressure member extending around and compressing said one section.

2. A tube comprising longitudinally abutting alternately outwardly and inwardly attenuated ring-sections, the inwardly attenuated sections being outwardly extended to touch each other.

3. A tube comprising longitudinally abutting alternately outwardly and inwardly attenuated ring-sections, of substantially trapezoidal cross-section, the inwardly attenuated sections being outwardly extended to touch each other, and a plastic disposed in the space confronted by the outside of the outwardly attenuated sections between the sides of the inwardly attenuated sections.

4. A tube comprising longitudinally abutting alternately outwardly and inwardly attenuated ring-sections, the inwardly attenuated sections being outwardly extended to touch each other, and parallel faces upon said inwardly attenuated sections at which they abut upon each other to the outside of said inwardly attenuated sections.

5. A tube comprising longitudinally abutting alternately outwardly and inwardly attenuated ring-sections of trapezoidal and triangular cross-sections, respectively, the inwardly attenuated sections being outwardly extended to touch each other, and parallel faces upon said inwardly attenuated sections at which they abut upon each other to the outside of said inwardly attenuated sections.

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