United States Patent

Hoshino et al.

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[54] **SEALING METHOD OF SEALED SEGMENTS OF A TUNNEL**

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[52] **U.S. Cl.**.....**61/42,** 61/45 R, 29/450, 277/228

[51] **Int. Cl.** **E21d 11/08**

[58] **Field of Search** 61/45, 42, 43, 84, 85; 29/450; 277/199, 207, 228

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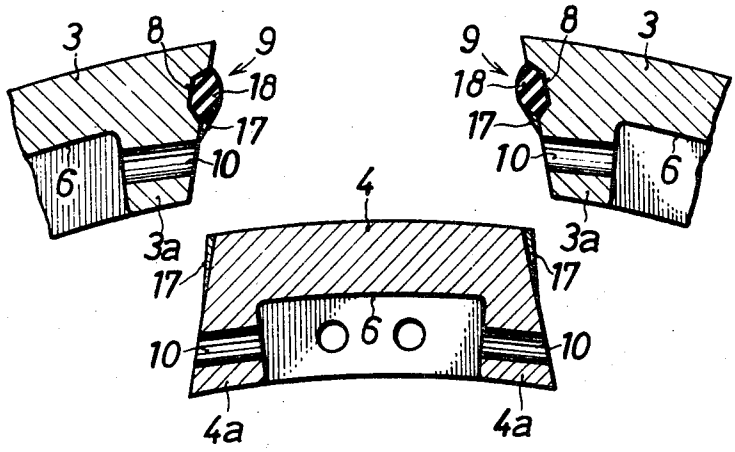
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[57] **ABSTRACT**

The present invention relates to a method of sealing segments of a tunnel, wherein a groove is formed in the direction of breadth of at least one of opposite sides to be united, which are adjacent, between respective segments, which constitute an annular body as well as between respective annlar bodies in the direction of length of a tunnel, and in said groove are projectively fixed a hard elastic core materials and a soft elastic coating materials which cover the exposed side of said core materials., and said sealing materials are held between said adjacent materials, so that, by interposing and stitching sealing materials, said adjacent segments are united.

6 Claims, 9 Drawing Figures



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SHEET 1 OF 2

FIG. 1

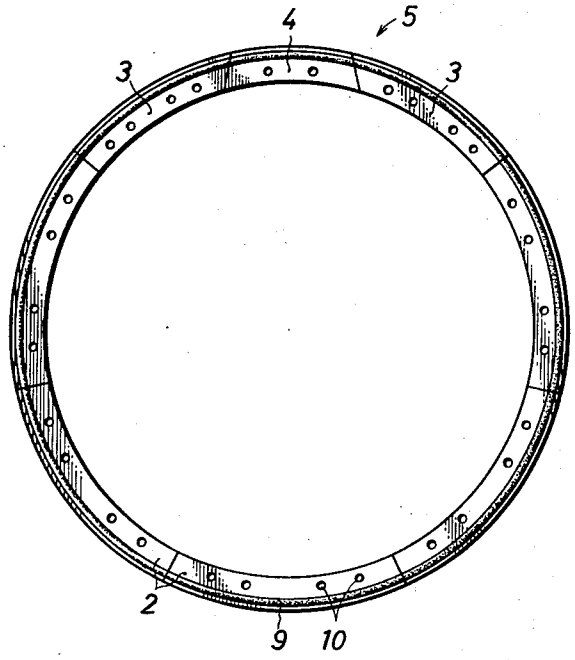


FIG. 9

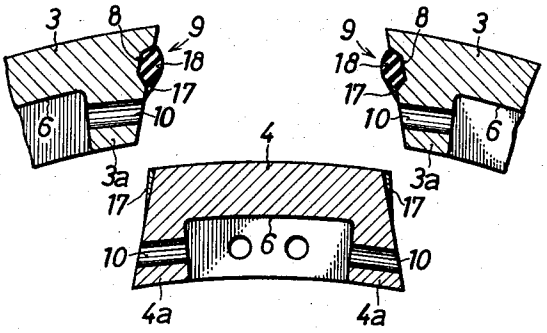
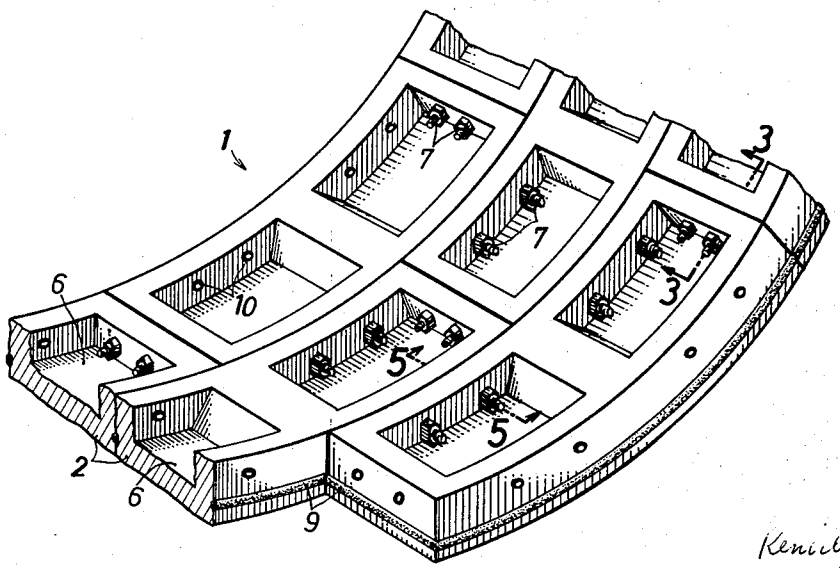


FIG. 2



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FIG.3

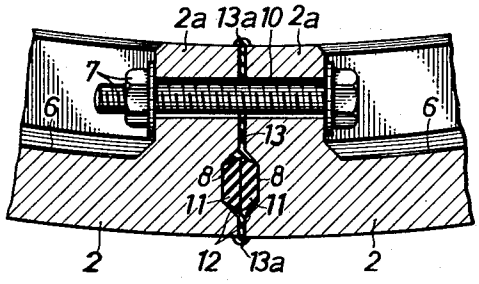


FIG.4

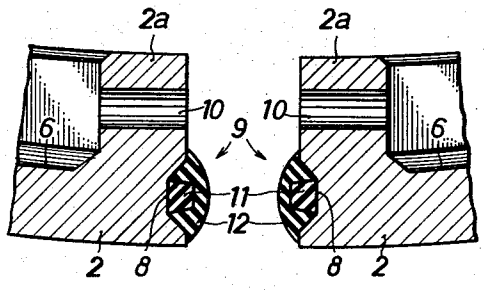


FIG.5

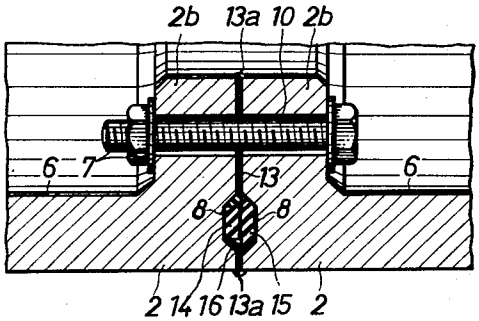


FIG.6

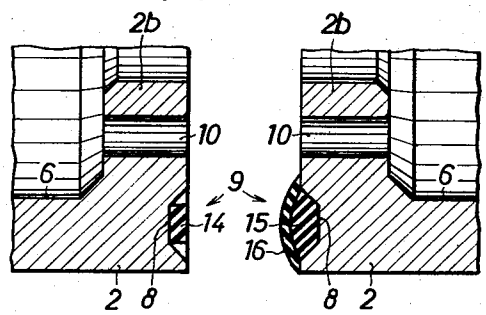


FIG.7

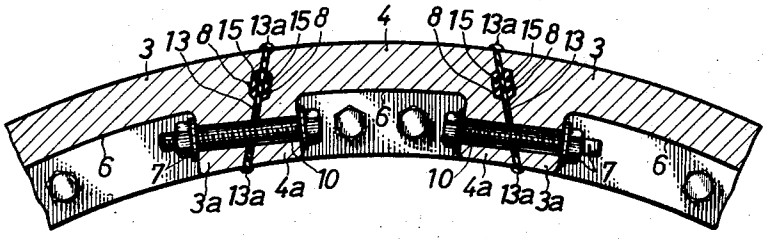
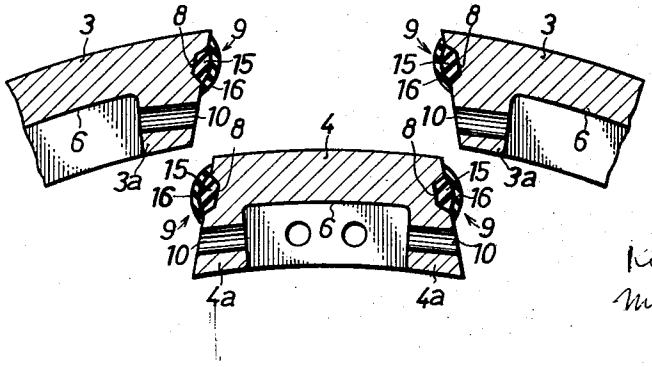


FIG.8



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SEALING METHOD OF SEALED SEGMENTS OF A TUNNEL

to a method of sealing segments, and more particularly to a method of sealing adjacent segments, which is used when a tunnel is constructed by sealing work between respective segments which form part of an annular body as well as succeeding annular bodies in the direction of length of the tunnel.

When constructing a tunnel by the sealing work, several arc-shaped segments are closely united, lastly inserting a key segment between two upward segments to form an annular body, and many of such annular units will be closely arranged in the direction of length of the tunnel. Consequently, in respective joints of segments between arc-shaped segments, a key segment and two segments on both sides of said key segment, all of which form an annular body, sealing will be carried out by the use of sealing materials, so that a underground water and the like may not come into the tunnel.

The conventional techniques adopted as a sealing method of respective segments, however, are only to paste a rubber type sealing material on united sides of segments and, when united sides of a segments, made of concrete, are rough, it is difficult to expect complete prevention of leakage between segments. In addition, there will often be a breakage or exfoliation of sealing materials, so that a conventional method have many disadvantages.

One of the objects of the present invention is to provide a method of sealing segments which serves to make the construction work of a tunnel easy and efficient.

Another objects of the invention is to provide a method of sealing which always assures a water tight seal between segments even when the sides of the segments are rough or when there will be some irregularities in joint gaps of segments.

One of further objects of the invention is to provide sealing material which can be easily made and fixed well to the segments, and which can prevent leakage between segments.

In short, the method of sealing segments according to the present invention comprises the process of forming a groove in the direction of the sides of at least one of adjacent segments, fixing elastic sealing material in said groove to a thickness greater than the depth of said groove, and uniting said adjacent segments by causing said sealing materials between the two segments to stretch out.

The present invention and other objects and advantages thereof will be more fully understood by reference to the accompanying drawings and following detailed description, wherein:

FIG. 1 is a side view of an annular body which is a constituent unit of a tunnel, wherein the sealing method of the present invention is applied to the respective segments.

FIG. 2 is a partially enlarged oblique view showing the united condition of a plurality of segments of FIG. 1.

FIG. 3 is a section taken along line 3—3 of FIG. 2.

FIG. 4 is a section showing a separated condition of adjacent segments of FIG. 3 before they are united.

FIG. 5 is a section taken along line 5—5 of FIG. 2.

FIG. 6 is a section showing a separated condition of adjacent segments of FIG. 5 before they are united.

FIG. 7 is a longitudinal section showing the united condition of the key segment and its adjacent segments on both sides.

FIG. 8 is a longitudinal section showing a condition in FIG. 7 before the key segment is inserted between adjacent segments on both sides.

FIG. 9 is a longitudinal section which shows a modified embodiment of the invention and which corresponds to FIG. 8.

As shown in FIG. 1 and 2, the tunnel 1 is made of annular bodies 5 which are formed with a plurality of normal segments 2, bent in conformity with the diameter of the tunnel 1 and which are united, the key segments 4, which is lastly inserted in the top section of the tunnel has adjacent segments 3 on both sides to hold it between them. The annular bodies 5 are successively assembled cylindrically in a close condition. When the annular bodies 5 are united, both sides of the respective segments are caused to slightly slip off each other, so that the joint of said segments will never be in single file. All segments 2, 3 and 4 are made of reinforced concrete and upon their respective inner sides are provided a suitable number of dents 6. The adjacent segments are all united by means of bolts and nuts 7, while a groove 8, both sides of which are inclined so as to separate wider outwardly, is provided at in the face where adjacent segments meet together and in the direction of length of the oppositely united outward sides of all segments 2, 3 and 4 constituting the tunnel 1. In said groove 8 are inserted elastic sealing materials 9 which project outwardly and fixed by means of an adhesive. In FIG. 3 and 4 are shown the united condition of normal segments 2 joined up an annular body 5. At the inside position of a radial wall 2a of both segments is opened a bolt hold 10, and into a groove 8 situated outside the segment are fixed the elastic materials by means of an adhesive. Said elastic materials are composed of hard elastic core materials 11 and soft elastic coating materials 12 cylindrically. The section of said elastic core materials is trapezidal. Its breadth is narrower than the groove 8 and a part of the coating materials 12 covers both side sections of the groove 8, while the coating materials 12 inclusive of a part of said core materials 11 project outside the wall 2a in a condition prior to their being united mutually. (See FIG. 4) When both segments 2 are strongly united by means of the bolt and nut 7, said core materials of the sealing materials 9 will be pressed to spread out in the direction of breadth of the groove 8 and at the same time the coating materials 12 are pressed from both sides to stretch out and become sealing materials 13. Further, its inside and outside stretched tips 13*a*, protrude inside and outside both segments 2 to completely cover the joints between the solid segments 2. (See FIG. 3)

In FIGS. 5 and 6 are shown the uniting of between the segments 2 of annular body 5. The same conditions are likewise seen in the case of other segments 3 and 4. On the side where the annular body 5 of segments 2 are mutually united, a vertical wall 2*b* with a bolt hole 10 is formed. The sealing between two adjacent annular bodies 5 is carried out by binding them by the use of a jack for a sealing purpose, and the elastic sealing materials 9 of the segments 2 on the side to be pressed by the jack will be only a hard elatic body 14, whose cross section is trapezoidal. It is so formed as to have a

thickness which will not project out of the groove **8**. The elastic sealing materials **9** of the segments **2** on the pressing side are composed of hard elastic core materials **15** and soft coating materials **16**, and said core materials **15** is inserted closely into the groove **8**, having a cross sectional shape slightly projecting out of the groove **8**, while the coating materials **16** has a gently curved surface and covers the exposed surface of the elastic materials **9**.

In FIGS. **7** and **8** are shown the sealed condition of the key segment **4** and adjacent segments **3** on both sides to hold it between them. The key segments **4** has two inclined walls **4***a* which are narrowed outward, while the segments **3** which hold the key segment **4** between them are provided with inclined wall **3***a*, which has an inclined side that agrees with the inclined wall **4***a* only on the side which contacts the key segment **3**. In the walls **4***a* and **3***a* there are bolt holes **10**. The shape and the structure of elastic sealing materials fixed into the grooves **8** of the walls **4***a* and **3***a* are the same as the ones on the right side of FIG. **6**, and it will be easily understood that the elastic sealing materials **9** will be pressed between the segments and become stretched out and the stretched tip **13***a* covering inside and outside the joint of segments will be formed in the same way as described heretofore.

In FIG. **9** is shown a modified example of the sealing method of the joint between the key segment **4** and its adjacent segments **3** holding the key segment. In the inclined wall **4a** of the key segment **4**, no groove is formed, but only the inclined wall **3***a* of the segments holding the key segment between them is provided with the groove **8**, into which are fixed the sealing materials **9** composed of the hard elastic materials **14**, **19**, while in addition to said sealing materials **9**, pasty materials **17** are thinly fixed downward and inward of said sealing materials **9** in such a way as to be thicker upward and thinner downward. In a like manner are fixed said pasty materials **17** from the upper end of the inclined wall **3***a* of the key segment **3** to the nearly middle height of said wall **3***a*. When the key segment **4** and its adjacent segments **3** on both sides are sealed, the elastic materials **9** will be in the same condition as shown in FIG. **7**.

The hard elastic core materials **11**, **15** and the hard elastic materials **14–18** which constitute the above mentioned elastic materials **9** as well as the soft elastic coating materials **12** and **16** are all made of the rubber materials, such as for instance: natural rubber, styrene butadiene rubber, acrylonitrile butadiene rubber, polychloroprene rubber, acrylic ester-acrylonitrile rubber soprene rubber isobutylene-isopropylene rubber, ethylenepropylene terpolymer, epichlorohydrin rubber, propyleneoxide-epichlorohydrin rubber, ethleneoxide-epichlorohydrin rubber, ethylene vinyl acetate copolymer, ethylene-acrylic ester copolymer, chlorinated polyethylene, chlorinated polypropyrene, polyurethene rubber, chlorinated butyl rubber, polybutadiene rubber, chlorosulfonic polyethylene etc., and by adding a softener the hardness can be controlled as required. As the softener for this purpose polybutene, lubricating oil, process oil, liquid paraffin, vaseline, ozokerite, caresin, gilsonite, petroleum asphalt, mineral rubber, petroleum resin, coal-tar, cumarone-indene resin, vegetable oil, chlorinated - paraffin, epoxide derivative, polyester alkyd resin,

The hard elastic core materials **11** and **15** and hard elastic body **14**, **18** have the shore A hardness of about 10° – 80°. They are suited for the purpose, if they have a dynamic recovery of more than about 50 percent. Their blending examples are as follows:

Natural rubber	100 weight parts
Zinc white	5 weight parts
Sulphur	8 weight parts
Stearic acid	2 weight parts
Dixie clay	50 weight parts
Thermal black	10 weight parts
Dibenzole disulfide	1 weight parts

The hard elastic body and the hard elastic core material obtained by blending the above-mentioned components and vulcanizing at 160° for 30 minutes have shore A hardness 50°, tension 240 kg/cm², maximum elongation percentage 650 percent and dynamic recovery 95 percent.

Blending Example 2.	
Butyl rubber	30 weight parts
Chlorinated Butyl rubber	40 weight parts
Stearic acid	1 weight parts
Zinc white	10 weight parts
Paraffin	3 weight parts
Thermal blank	100 weight parts
Reacted phenol resin	13 weight parts
Zinc chloride	3 weight parts
Process oil	60 weight parts

The hard elastic is body obtained by blending the above-mentioned components and vulcanizing at 160° for 30 minutes have shore A hardness 20°, tension 25 kg/cm, maximum elongation percentage 1,000 percent and dynamic recovery about 90 percent.

The soft elastic coating materials **12** and **16**, which have shore A hardness less than 30 percent, are suited for the purpose, and it is desirable that they become very thin, if pressed down, but they will have a proper dynamic recovery after said pressure is removed, and that they will be hardened in the course of time, while they stick fast to the surface of segments and blend well with the hard elastic core materials **11**, **15** or the hard elastic body **14**, **18** to be united in a body. Desirable blending examples are as follows:

Blending Example 1.	
Butyl rubber	80 weight parts
Reclaimed butyl rubber	40 weight parts
Soft clay	100 weight parts
Thermal black	50 weight parts
Polybutene	100 weight parts

The soft coating materials obtained by blending at an embient temperature have shore A hardness 15°, tension 0.4 kg/cm² and maximum elongation percentage 1,500 percent. When their cross section is a regular square covering a space of 30 mm², and they have the length of 10 mm, their thickness has become less than 0.1 mm, if pressed down with 100 kg/cm² jack pressure.

Blending Example 2.	
Butyl rubber	60 weight parts
Chlorinated butyl rubber	40 weight parts
Polyethylene	25 weight parts
Polybutene	180 weight parts
Reacted Phenol resin	10 weight parts
Zinc chloride	3 weight parts
Soft clay	50 weight parts
Thermal black	10 weight parts

The soft elastic coating materials have been obtained, which have shore A hardness 5°, tension 0.4 kg/cm² and maximum elongation percentage 2,000 percent by blending the above-mentioned components and vulcanizing at 160° and, if they are pressed down with 100 kg/cm² jack pressure, they have produced a deformation which is the same as the aforesaid blending example 1.

The sealing materials **9**, which have been made cylindrical by uniting the core materials **11**, **15** with the coating materials **12** or **16**, are pasted to the segments with an adhesive when assembling when a heat soluble adhesive is first applied to the bottom section of the sealing material **9** and then heated to melt it to paste the following adhesives will be used: polypropylene, epoxide resin, polyamide resin, ethylene vinyl acetate copolymer, acrylate resin, butyral resin, ethylene acrylate copolymers and cumarone-indene resin etc.

For the second bonding means, which are not used, if an adhesive has already been applied to the bottom side of the sealing material **9**, or when said sealing material **9** already have adhesive property, but are used, when their adherent surface is covered by a parting paper which will be peeled off, when starting work, and they are pressed together to adhere to each other, following adhesives are used; natural rubber, polyacrylate resin, polyisobutylene, butyl rubber and polyvinyl butyl ether etc.

For the third bonding means which are used, when an adhesive of the solvent evaporation type has already been applied to the bottom side of the sealing material **9** and dried up, but again damped with a solvent before starting work so as to immediately be pasted, the following adhesives are used: vinyl acetate resin, vinyl chloride resin, butyral resin, chloroprene rubber, natural rubber, chlorinated rubber, reclaimed rubber, polyamide resin, asphalt and coal tar etc. and, like these adhesives are not used, when the sealing material **9** has adhesive properties.

For the fourth bonding means which are used when an adhesive of the solvent evaporation type or the chemical reaction type is applied to the bottom side of the sealing material **9** to be pasted immediately upon the sides of segments, the following adhesives are used; poly vinyl acetate resin, polyvinyl chloride resin, butyral, resin, chloroprene rubber, natural rubber, chlorinated rubber, reclaimed rubber, polyamide resin, asphalt, coal-tar, epoxide resin, unsaturated polyester, cyano aclylate, vinyl monomer, silicone resin, polymethane resin, phenol resin and xylene resin etc.

The past type material **17** is made by adding organic or inorganic fillers or plasticizers to the synthetic rubber or the synthetic resin or their mixtures, such as butylrubber, polysulfide rubber, ethylene propylene rubber, epoxide resin, acrylic resin and ethylene vinyl acetate copolymer etc., so that they may be in a pasty condition. It is desirable that, in view of their being watertight more complete and lasting, they will be hardened in the course of time and they are soluble with the sealing materials **9** to become a solid body.

A desirable blending example of the paste type material is as follows:

Butyle rubber	100 weight parts
Calcium carbonate	50 weight parts
Carbon	50 weight parts
Polybutene	60 weight parts
White kerosene	60 weight parts
Dimethyl dioctadecyl ammonium bentonite	4 weight parts
Ethyl alcohol	10 weight parts

If the above-mentioned components are blended, the resultant pasty matter has the viscosity of 15,000 poise and its hardening time is 1 week.

It should be noted that respective segments can be made completely watertight by the method of the present invention, which also can be applied to segments made of cast iron, cast steel, and made from metallic plate as well as wood. In consideration of various points to be sealed, the cross-sectional shape of the elastic sealing materials is so chosen as to be most suitable for complete sealing.

What is claimed is:

1. A method of sealing two segments of a tunnel lining, said segments having inclined faces joined by a key segment which is to be held between said two segments, comprising the steps of:

a. forming a groove in the direction of the breadth of the two faces to be united;

b. fixing an elastic sealing material in said groove to protect outwards, said sealing material having a thickness greater than the depth of said groove, said sealing material being composed of a hard elastic core material and a soft elastic coating material which covers the exposed side of said core material, a part of said elastic coating materials being inserted into said groove so as to put said sealing material between said two faces and the faces of said key segment in order to join said faces and unite said segments; and,

c. forcibly uniting the faces of said segments with the corresponding faces of said key segment, whereby said hard elastic core material is stretched in the direction of the breadth of the groove so as to substantially fill said groove and said soft elastic coating material is stretched to fill the joints between adjacent faces.

2. A method of sealing two segments of a tunnel lining, said segments having opposing inclined faces comprising the steps of:

a. forming grooves in the direction of breadth of the faces to be united;

b. holding a key segment between said opposing faces so that said key segment can be pushed between said opposing faces;

c. fixing in said groove an elastic material to project outwards, said material having a thickness greater than the depth of said groove, said elastic material being composed of at least one hard elastic core material and at least one soft elastic coating material covering the exposed side of said core material;

d. extending the surface of said plastic coating material gently in an arc-shape to both edges of said groove, so that adjoining segments including said key segment may be united with each other when said sealing material between said segments is extended out; and,

e. forcibly uniting the faces of said segments with the corresponding faces of said key segment, whereby said hard elastic core material is stretched in the direction of the breadth of the groove so as to substantially fill said groove and said soft elastic coat-

ing material is stretched to fill the joints between adjacent faces.

3. A method of sealing together stone-like segments of a tunnel lining having opposed longitudinal inclined faces, comprising the steps of:

a. forming a groove in both inclined faces in the direction of breadth of an upper part of said faces to be united;

b. disposing a key segment to be held between said opposite faces;

c. fixing in said groove at least one hard elastic material having an arcuate outer surface and a breadth greater than the depth of said groove, while coating said elastic sealing material in the area adjoining a lower part of the faces to be united with a paste type material so as to hold said key segment therebetween and further coating said paste type material on said key segment in the direction of the upper part of said faces to be united, so that said adjoining segments may be united when stretching said elastic material and the paste type material between said faces; and,

d. forcibly uniting the faces of said segments with the corresponding faces of said key segment, whereby said hard elastic material is stretched in the direction of the breadth of the groove and said paste type material fills the joints between adjacent faces.

4. A method of sealing stone-like arcuate segments of a tunnel comprising the steps of:

a. forming a contoured-shaped groove in each of the opposing faces of each segment in conformity with the contours of the segments;

b. fixing in the grooves of each segment a hard elastic material nearly equal to the depth of said groove, while providing in the groove of at least one segment a soft elastic material, which covers the exposed side of said core material and projects outwardly from said groove, said projecting elastic material being put between said faces so as to stretch out so that all said adjacent segments are united; and,

c. forcibly uniting the opposing faces of said segments, whereby said hard elastic materials are stretched in the direction of the breadth of the grooves so as to substantially fill said grooves and said soft elastic material is stretched to fill the joints between said faces.

5. A method according to claim 4 wherein the soft elastic material is provided in the grooves of each of the opposing faces of each segment.

6. A method according to claim 4 wherein adjacent segments are united so as to form a tunnel, the tunnel being completed by the combination of said segments with one key segment.

* * * * *