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TUNNEL LINING

5 This invention relates to segmental linings for tunnels, galleries and similar underground works, in which individual lining segments made of reinforced concrete are braced with each other both in the annular or peripheral direction and in the longitudinal direction with the aid of tension rods, provided with tensioning elements, which connect neighbouring segments and extend in channels in the segments.

10 Segmental tunnel lining as just described is, for example, described in the publication "U-Bahn München Baulos 8/1-7.1". In this known lining the individual segments have on their inside cassette-like indentations having a comparatively large

15 surface area and limited all around by side walls out of which there project the tension rods which are to be provided with the tensioning elements. On account of the narrow spatial conditions resulting from the cassette side walls, apart from smaller

20 auxiliary implements, larger tensioning machines, such as impact screwing apparatus, for effecting mutual bracing of the individual segments can hardly be applied or cannot be applied at all on the tensioning elements so that only imperfectly closed joints

25 can be made. Furthermore, on account of the weakening of the individual segments, which is caused by the indentations and gives rise to cracking, anchorage

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of the tension rods in the concrete of the segments, which copes with all stresses, is not possible. The consequence of imperfectly closed joints, or the unsatisfactory anchorage, are concrete chipping in the joint region, leakages and also unplanned deformations of, and stresses on, the finished tunnel tube, for reasons which will next be discussed.

In so far as sealing members are provided in the ring-type joints, these sealing profiles where tunnel construction is effected utilising shield advance are only compressed through the driving presses of the shield which exert longitudinally directed pressure forces onto the tunnel tube. In the course of the shield advance these pressure forces are removed in terms of time and area. As a result of this, the sealing members relax and the ring-type joints open again. The sealing members in the longitudinal joints are not compressed whilst lining assembly takes place in the protection of the shield tail. Only when the shield has driven up, the longitudinal joints are partially closed through the radial loads which then act on the lining as a result of annular gap grouting, water pressure and rock pressure.

As a result of the undefined gaps in ring-type and longitudinal joints, in turn resulting from methods of construction and load conditions, the finished tunnel tube varies from the planned form. These variations are intensified through stresses of the tunnel tube outside the shield tail, for example through an uneven pressure distribution along the periphery in the case of annular gap grouting and through the necessary longitudinal action of the tunnel tube in the region where the annular gap grouting has not yet hardened. The variations in form result in a situation where the practically rigid reinforced concrete lining segments no longer

fit on each other exactly enough. At the joints, cracks or displacements can arise. The loads acting upon the tunnel cannot be taken up as planned by the joint surfaces which are provided therefor and concrete chipping results.

The deformations due to the unavoidable longitudinal structural conditions of the tunnel outside the shield tail can lead to a rupturing of the ring-type joints and therewith to leakages. The water-proofness of the longitudinal joints is only attained through the compression of sealing profiles in joints through the radial load as a result of annular gap grouting, water and lock pressure, and this is only possible if the joints lie outside in the protection of the shield tail. In order to avoid penetration of fine particles of earth into the joints and between the sealing profiles which are not yet compressed, in the case of the joint constructions which are known at present, a special strip of rubber is inserted into the joint split outside the actual sealing members. The sealing effect of such a strip of rubber in respect of earth and pressurised water is naturally uncertain. The risk that the actual sealing members will lose their operatability before the compression of the longitudinal joints is thereby great.

According to the present invention there is provided segmental linings for tunnels, galleries and similar underground works, in which the individual lining segments, which are made of reinforced concrete and which can be joined together to form rings which can be connected with each other, form longitudinal joints extending in the longitudinal direction; in which neighbouring segmental lining rings can be connected with each other thus forming ring-type joints extending crosswise in respect of the longitudinal direction, for which purpose the individual lining segments have channels for longitudinal tension rods

extending in the longitudinal direction for the accommodation of at least one of them in each case and the longitudinal tension rods of neighbouring lining segments of consecutive lining rings can be connected with each other by way of tensioning nuts open on both sides, forming, in each case, continuous tensioning elements in the region of the ring-type joint; and in which the channels accommodating the longitudinal tension rods are enlarged conically in the region of the ring-type joint of the lining segments for the purpose of accommodating the tensioning nuts; wherein the lining segments can be connected into a ring by way of straight tension rods, which can be braced, and the tension rods, which serve this purpose, of each ring and the channels accommodating them extend crossing at an oblique angle in each case the longitudinal joint present between two neighbouring lining segments of a ring, and each ring tension rod can be fixed with one of its ends in an anchor element firmly mounted in respect of the associated lining segment; wherein the anchor element is arranged embedded in the concrete of the lining segment at a distance from the longitudinal joint at the end of the channel accommodating the ring tension rod and the ring tension rod projects with its other end into a recess which is provided in the neighbouring lining segment, which extends substantially in the direction of the channel accommodating it, which opens out at the interior surface of the lining and which has a contact surface which extends crosswise in respect of the axis of the ring tension rod and which can be braced against the threaded nut which can be screwed onto the end of the ring tension rod. There are hereby created segments in which closed joints can be attained as planned in a simple and safe way.

35 The advantages attained lie in the fact that through the firm connection for the anchor element with the segment and the free accessibility of the tension

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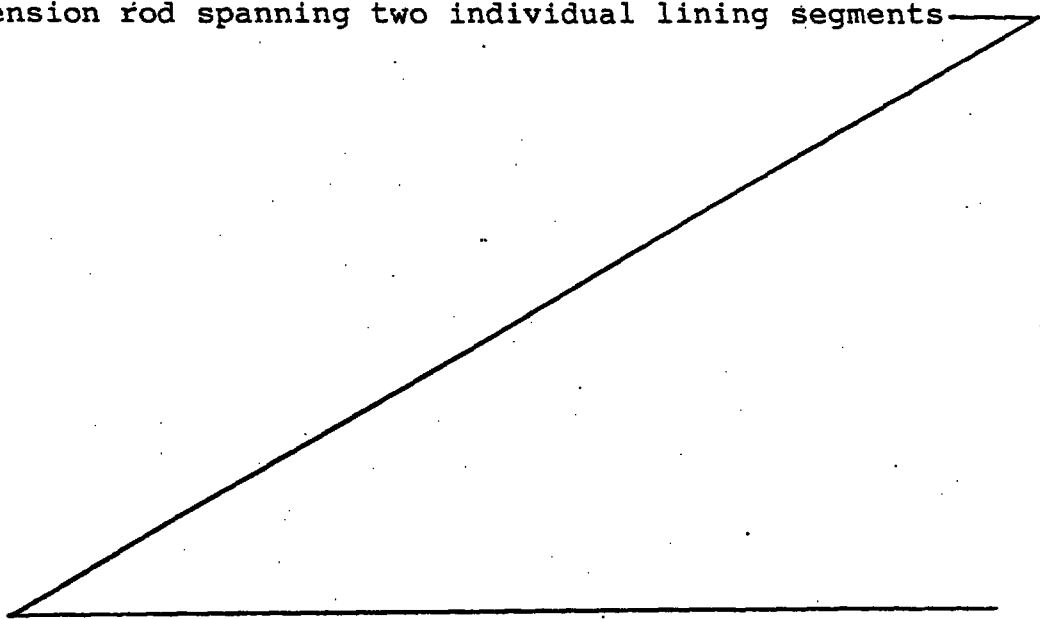
rod end, which is opposite the anchor element, the application of an effective tensioning machine, for example of an impact screwing apparatus, on the tensioning element is possible whereby a bracing of the individual segments is attained in the case of joints which are closed as planned. In addition, the danger of cracking is eliminated because weakenings of material, as are caused through cassette-like indentations having a comparatively large surface area, are not present.

There will also be described a measuring instrument for checking the joint width between segments as defined above, out from the inside of the construction, comprising a wedge which can be inserted into the joint and which according to possible depth of insertion has a stop or visible mark working together with the inside of the construction.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made by way of example, to the accompanying drawings, in which:-

Figure 1 is a developed view of a tunnel lining made up of segments, as viewed from inside the tunnel,

Figure 2 is a radial section through a ring tension rod spanning two individual lining segments



where they meet in a longitudinal joint,

Figure 3 is an axial section through a longitudinal tension rod spanning two individual segments where they meet in a ring-type joint,

5 Figure 4 is a sectional view of two individual segments where they meet,

Figure 5 is a cutaway portion, turned through about 45°, from Figure 1 and on an enlarged scale,

10 Figure 6 is a section on line VI-VI in Figure 5,

Figure 7 is an axial section through a tooth construction of two individual segments meeting in a ring-type joint,

15 Figure 8 is a section taken on line VIII-VIII in Figure 7,

Figure 9 is a section taken on line IX-IX in Figure 7,

Figure 10 is the cutaway portion designated at X in Figure 7, drawn on an enlarged scale,

20 Figure 11 shows a variation of what is shown in Figure 10,

Figure 12 shows a further variation of what is shown in Figure 10, and

25 Figure 13 is a section taken on line XIII-XIII in Figure 10.

30 As illustrated, a certain number of, for example eight, individual tunnel lining segments 1 and a keystone form a ring. Between the individual rings there are found, for example according to Figure 1, ring-type joints 13 while longitudinal joints 7 are found between the individual segments. The longitudinal joints 7 of each ring are arranged displaced with respect to the longitudinal joints 7 of the neighbouring ring.

35 The segments 1, which are made of reinforced concrete, are braced one with another both in annular or peripheral direction and in longitudinal direction

with the aid of tension rods 3, 4 which connect neighbouring segments and which extend in channels 2 (Figures 2 and 3) for which there is provision in each segment, and tensioning elements 5 corresponding to these.

As shown in Figures 2 and 3, each segment 1 has no less than one anchor element 6, which is firmly connected with it at least in the built-in state, for the purpose of anchoring the tension rod 3, 4 which effects the connection with the neighbouring segment 1. The tensioning element 5, which is arranged on the end of the tension rod 3, 4 opposite the anchor element 6, is, at least until the next segment 1 is built in, freely accessible for the application of a tensioning machine, for example, of an impact screwing apparatus 34, which is indicated in chain lines in Figure 2, in the direction of the elongated shaft of the tension rod.

Referring to Figure 2 the ring tension rods 3, which serve the purpose of bracing in annular or peripheral direction, extend in each case in such a manner that - in radial section (Figure 2) - they cross at an oblique angle in each case the longitudinal joint 7 present between the two neighbouring segments 1. In detail, the construction is such that the end, which is opposite the anchor element 6, of each ring tension rod 3 opens out into a hollow 9 which is arranged on the segment interior surface 8 and which has a wall portion 10 which extends crosswise to the shaft of the ring tension rod and contributes to the installation of the tensioning element 5. Both ends of each ring tension rod 3 are provided with screw threading. The anchor element 6 includes a threaded sleeve 11 embedded in concrete. The tensioning element 5 includes a tensioning nut 12. The anchor element 6 including the threaded sleeve 11 receives the shaft of the

ring tension rod 3 at a distance at least 15 cm from the longitudinal joint 7. By this means on the one hand a situation is reached where a perfect transfer of the prestressing forces from the screw anchorage to the ring reinforcement of the segment 1 is possible. On the other hand, the greater length of the ring tension rods 3 which is attained thereby is necessary in order to limit the bending stress of the tension rods 3. This stress then appears when the segment 1 is directed in tangential direction when prestressing. In the construction according to Figure 2 the hollows 9 can in respect of breadth, width and depth be essentially smaller than in the case of the known cassette-like indentations. The danger of cracking of, and leakages in, the individual segments is considerably reduced still further thereby.

Referring to Figure 3 the construction is such that the longitudinal tension rods 4, which serve the purpose of bracing in the longitudinal direction, in each case with formation of a continuous prestressing element, are connected with each other by means of connection elements. Both ends of each longitudinal tension rod 4 are provided with screw threading. One end projects out of the ring front surface 14 of the segment 1 which is facing the ring-type joint 13 present between two neighbouring segments. Onto this end there is screwed the connection element which simultaneously forms the tensioning element 5 for the one longitudinal tension rod 4 and the anchor element 6 for the next longitudinal tension rod 4. This connection includes a tensioning nut 15 open at both ends, which bears at one end by way of a ring flange 35 against the ring front surface 14 of the segment and into whose other end the end of the next longitudinal tension rod 4 is screwed. The individual longitudinal tension rods 4 can be simultaneously prestressed and coupled

in a simple manner as the rods 3 in the ring-type joints 13. As a result, before the segment which is next in the longitudinal direction is built in, an impact screwing apparatus can be applied onto the tensioning element 5 without hindrance.

The channels 2, which are provided in the segments 1 and which receive the tension rods 3, 4, are at least partly conically formed. As shown in Figure 2, of the channels 2 receiving the ring tension rods 3, only the channel portions 2a which lead to the anchor element are constructed conically, tapering out from the longitudinal joint 7. As shown in Figure 3, the channels 2 receiving the longitudinal tension rods 4 are constructed conically enlarging out from the ring front surface 14 which forms an installation for the one end of the connection element. Such conical construction makes possible a subsequent insertion of the tension rods 3, 4 taking into account manufacturing and assembly tolerances.

Furthermore, from the channels 2 which receive the tension rods 3, 4, there extend injection channels 16 which open out at the segment interior surface 8 and which render possible the insertion of a suitable injection agent for the formation of protection against corrosion, or of an adhesive compound for the tension rods 3, 4.

In the ring-type joints 13 and in the longitudinal joints 7 in each case two sealing elements 17, which are provided at a radial distance from each other, corresponding to the segment are arranged in a circular or continuous manner. The sealing elements 17 can be formed by profiled rubber strips or strips made of similar material. As a result, the construction is such that both sealing elements 17 are arranged in radial direction symmetrical to the central surface of the tunnel shell or to the tunnel shaft and to the centre of

gravity of the joint contact surfaces which are statically effective. By this means, bending moments due to eccentrically operating restoring forces of the sealing elements 17 in the joint 7, 13 are avoided.

5 The prestressing of the ring and longitudinal screwing takes place when assembling the segments through impact screwing apparatus in such a way that the applied prestressing forces exert excess pressure on the restoring forces of the sealing
10 elements 17 and the frictional forces in the joints 7, 13 with sufficient safety allowance and bring the concrete surfaces of the joints into pressure contact as planned. Both in the annular and in the
15 longitudinal direction, special auxiliary presses are used which bring the segments 1 into the planned position. As a result, in the first instance excess pressure can be exerted on the sealing elements 17 in the longitudinal joints through the auxiliary
20 presses and then the tensioning elements 5 can be tightened. The closing of the joints 7, 13 through prestressing the tension rods 3, 4, which is necessary for stability and waterproofness, takes place as planned in the protection of the shield tail (which is not represented) of a driving shield and is not
25 subject to the respective pressing of the driving presses 36 (Figure 1) or to the later radial tunnel load and the operatability of a rubber strip lying outside the actual sealing elements 17.

30 As the Figures show, the tension rods 3, 4 are arranged between both sealing elements 17.

35 In the embodiment according to Figure 4 the construction is such that for the purpose of toothing neighbouring segments 1 in one of the segment sides facing the joints 7, 13, there is arranged a recess 18 and in the other of the named segment sides there is arranged a projection 19 corresponding to the recess. The projection 19, which is made

of a smooth material, for example of synthetic material, is constituted by a round rod which projects by its semi-cross-section out of a groove 20 in which it is secured, for example in which it is cemented. Through this measure a mutual displacement of the segments 1 at the longitudinal joints 7 is avoided. Moreover, by this means, the off-drive forces are taken up as a result of the ring tension rod 3 which do not cross the longitudinal joint 7 at right angles.

Figures 7 to 9 show a construction with a radial tooth construction 21 of neighbouring segments 1, which is arranged in the ring-type joints 13 and which is constituted by a groove 22 in one of the two segment sides facing the ring-type joint 13 and a tongue 23 made of the segment material on the other of the named segment sides. This tooth construction 21 is provided with formation of naps having circular edges or slopes, spaced only at single points over the periphery of the ring-type joints 13, preferably at two points per segment. The groove 22 is, as a result, on account of its limited length in the face of chipping essentially less endangered than a continuous groove as provided in known constructions. The ends 24 of the tongues 23 pointing in the annular or peripheral direction form a tangential tooth construction with the grooves 22.

On account of the prestressing of the ring tension rods 3 and of the longitudinal tension rods 4 and on account of the tooth construction in radial and tangential direction, longitudinal structural action of the tunnel tube are made possible. More particularly, in the region behind the shield tail, where before the annular gap grouting hardens the elastic bedding of the tunnel is not yet given through the surrounding rock, deformations of the

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tunnel tube and the disadvantages connected with this for stability and waterproofness are avoided through the named measures.

5 In certain cases the longitudinal structural conditions of the tunnel can be of interest not only during the state of assembly but in the long run, for example in the case of elevated tunnels in inner-city regions where later construction measures near the tunnel tube cannot be safely precluded. The protection against corrosion of
10 the longitudinal and ring tension rods 4, 3, which is then necessary, can be attained through a subsequent injection which takes place by way of the mentioned injection channels 16.

15 According to Figures 5 and 6 the segment sides, which are provided for the pressure transfer and which are turned towards each other in the ring-type joints 13 or in the longitudinal joints 7, have chamfers 25 which taper off gradually to nil
20 from a crest value at the segment corners. The depth of each chamfer 25 is at least as great as the possible projections of the ring-type joints 13 in the longitudinal direction of the tunnel as a result of manufacturing and assembly tolerances.
25 By this means, a situation is reached where the longitudinal forces of pressure are not transferred at the corners of projecting segments 1, thereby avoiding chipping. Additional pads in the ring-type joints transferring pressure, as are used in
30 hitherto known joint constructions, are thus not necessary.

In the practical construction work the planned compression of the sealing elements 17 through the prestressing can be checked in a simple manner
35 with a measuring instrument 26, which is represented in Figures 10 to 13, for measuring the joint gap or joint width from the inside of the lining. The

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measuring instrument 26 has a wedge 28 which can be inserted into the joint 7, 13 and which according to possible depth of insertion has a stop 29 or visible marks 30 working together with the inside 27 of the construction. The wedge 28 is provided at its wide end with the stop 29 which when the joint width (Figure 12) is inadmissibly great on both sides of the joint 7, 13 enters into the inside of the construction. Furthermore, the wedge 28 has at its narrow end along the lines of a T a crossbar 31, whose lower edge, that is the edge turned towards the stop 29, which forms a visible mark 30, is flush with the inside 27 of the lining when the joint width is as desired, that is, when the joint 7, 13 is closed as planned (Figure 10 and 13). The stop 29 is constituted at the side, which is facing the wedge 28, by a haft 32 onto which a handle 33 is joined on the side turned away from the wedge.



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CLAIMS

1. Segmental linings for tunnels, galleries and similar underground works, in which the individual lining segments, which are made of reinforced concrete and which can be joined together to form rings which can be connected with each other, form longitudinal joints extending in the longitudinal direction; in which neighbouring segmental lining rings can be connected with each other thus forming ring-type joints extending crosswise in respect of the longitudinal direction, for which purpose the individual lining segments have channels for longitudinal tension rods extending in the longitudinal direction for the accommodation of at least one of them in each case and the longitudinal tension rods of neighbouring lining segments of consecutive lining rings can be connected with each other by way of tensioning nuts open on both sides, forming, in each case, continuous tensioning elements in the region of the ring-type joint; and in which the channels accommodating the longitudinal tension rods are enlarged conically in the region of the ring-type joint of the lining segments for the purpose of accommodating the tensioning nuts; wherein the lining segments can be connected into a ring by way of straight tension rods, which can be braced, and the tension rods, which serve this purpose, of each ring and the channels accommodating them extend crossing at an oblique angle in each case the longitudinal joint present between two neighbouring lining segments of a ring, and each ring tension rod can be fixed with one of its ends in an anchor element firmly mounted in respect of the associated lining segment; wherein the anchor element is arranged embedded in the concrete of the lining segment at a distance from the longitudinal joint at the end of the channel accommodating the ring tension rod and the ring tension rod projects with its other end into a recess which is provided in the



5 neighbouring lining segment, which extends substantially in the direction of the channel accommodating it, which opens out at the interior surface of the lining and which has a contact surface which extends crosswise in respect of the axis of the ring tension rod and which can be braced against the threaded nut which can be screwed onto the end of the ring tension rod.

10 2. Segmental linings according to claim 1, wherein the longitudinal tension rods, which serve the purpose of bracing in the longitudinal direction, are connected with each other by means of connection elements.

15 3. Segmental linings according to claim 2, wherein both ends of each longitudinal tension rod are provided with screw threading, wherein one end of each such rod projects out of the ring front surface of the associated segment which faces the ring-type joint present between two neighbouring segments and has screwed on to it the connection element which simultaneously forms the tensioning element for the one longitudinal tension rod and the anchor element for the next longitudinal tension rod, and wherein this connection element includes a tensioning nut open at 20 both ends which bears at one end against the ring front surface of the associated segment and into whose other end the end of the next longitudinal tension rod is screwed.

30 4. Segmental linings according to any one of claims 1 to 3, wherein of each of the channels receiving the ring tension rods, only the channel portion which leads to the anchor element is conical, tapering out from the longitudinal joint.

35 5. Segmental linings according to any one of claims 1 to 4, wherein each of the channels receiving the longitudinal tension rods enlarges conically out from the ring front surface which forms an installation for the one end of the connection element.



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6. Segmental linings according to any one of claims 1 to 5, wherein injection channels which open out at the segment insides extend from the channels which receive the tension rods.

5 7. Segmental linings according to any one of claims 1 to 6, wherein in the ring-type joints and/or in the longitudinal joints, two sealing elements which are provided with radial distance from each other, corresponding to the segments, are arranged in a
10 circular or continuous manner.

8. Segmental linings according to claim 7, wherein the tension rods are arranged between both sealing elements.

9. Segmental linings according to claim 7 or 8,
15 wherein both sealing elements are arranged in radial direction symmetrical to the central surface of the tunnel shell or to the tunnel shaft and to the centre of gravity of the joint contact surfaces which are statically effective.

20 10. Segmental linings according to any one of claims 1 to 9, wherein for the purpose of toothing neighbouring segments, in one of the segment sides facing the joints there is a recess and in the other of these segment sides there is a projection corresponding
25 to the recess.

11. Segmental linings according to claim 14, wherein the projection is constituted by a round rod which projects by its semi-cross-section out of a groove in which it is secured.

30 12. Segmental linings according to claim 10 or 11, wherein the projection is made of a material which has a smooth surface.

35 13. Segmental linings according to any one of claims 1 to 12, having a radial tooth construction of neighbouring segments, which is arranged in the ring-type joints and which is constituted by a groove in one of the two segment sides facing the ring-type

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joint and a tongue made of the segment material on the other of these segment sides; wherein the tooth construction is provided spaced only at single points over the periphery of the ring-type joints.

5 14. Segmental linings as claimed in claim 13, wherein the tooth construction is provided at two points per segment.

10 15. Segmental linings according to claim 13 or 14, wherein the ends of the tongues pointing in the annular or peripheral direction form a tangential tooth construction.

15 16. Segmental linings according to any one of claims 1 to 15, wherein the segment sides, which are turned towards each other in the ring type joints and/or in the longitudinal joints, have chamfers.

 17. Segmental linings according to claim 16, wherein the chamfer tapers off gradually to nil from a crest value at the segment corners.

20 18. Segmental linings for tunnels, galleries and similar underground works, substantially as hereinbefore described with reference to any of the embodiments illustrated in the accompanying drawings.

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