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DRAWINGS ATTACHED

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(54) IMPROVEMENTS IN TUNNELS OR TUNNELLING

(71) We, WILLIAM F. REES LIMITED, a British Company, of Old Woking, Surrey, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a method of constructing a lined tunnel, particularly those with a bore of about 1220 mm or less.

The invention provides a method of constructing a lined tunnel which comprises the steps of excavating a short length of tunnel within a shield of internal diameter greater than the external diameter of the lining to be erected, locating a first 120° lining segment within the inner periphery of the shield, engaging one circumferential end of each of two further 120° lining segments with respective circumferential ends of the first segment and pivoting, in turn, said two further segments outwards to bring the other ends of the two further segments into engagement to form a complete ring the axis of which is offset with respect to the axis of the shield, centralising the newly erected ring within the shield, jointing the newly erected ring to the previously erected ring, advancing the shield to a position in which a portion of the newly erected ring extends axially out of the rear end of the shield, injecting a filler material into the annular void between the portion of the newly erected ring projecting from the shield and the surrounding material left by the advancement of the shield whilst the ring is still supported co-axially with the shield by the shield, and then repeating the steps of excavating a short length of tunnel and erecting a lining ring within the shield in its advanced position.

In carrying out the step of erecting a ring, the first segment may be placed on the bottom of the shield and the other two segments are then placed above the first at opposite circumferential ends thereof to complete the ring, the clearance between the ring and the shield due to the difference in diameter being greater at the top of the ring than at the bottom.

The first segment may be held in position during the erection of the other two by a dowel pin engaging in sockets in the segment and the shield.

Radially inward pressure may be applied around the newly erected ring before it is locked to the previously erected ring, to effect circumferential pressure at the joints between the segments. The inward pressure may be applied by expansion under internal fluid pressure of a flexible annular tube between the shield and the ring.

The segments after they have been erected to form a ring may be held together by an external circumferential tie.

The segments may be formed with lines or regions of weakness extending in the axial direction of the ring whereby the rings can crack at controlled locations and deform to accommodate unevenly distributed external loads.

The invention also provides a lined tunnel when constructed by the method described above.

An example of the manner in which the method may be carried into effect will now be described with reference to the accompanying diagrammatic drawings in which:—

Figure 1 is a longitudinal section through a portion of a tunnel under construction,

Figure 2 shows half cross-sections on the lines A—A and B—B in Figure 1,

Figures 3 to 6 are cross-sections showing successive stages in the erection of a ring of segments,

Figure 7 is an enlarged view of the portion ringed in Figure 6,

Figures 8 and 9 are longitudinal sections of the upper portion of a ring of segments and related parts, in different stages of erection,

Figures 10 and 11 are end and side views of a completed ring, and

Figure 12 is a section on the line 12—12 in Figure 11 through a portion of a segment.

Referring first to Figure 1 the method is carried out within a circular steel shield 20, fitted with mechanical or hydraulic rams 21, a thrust ring 22, and a flexible annular tube 23.

The segments, three per ring, are transported within the already constructed work to the rear, i.e. into the skirt 24 of the shield (see also Figure 3).

The segments are all alike and extend over 120° of arc.

Segment (i) is then placed in the invert of the skirt of the shield and a temporary locating pin 25 is inserted through a preformed hole in the segment into a similar hole in the skirt of the shield. As seen in Figure 4 segment (ii) is moved forward and one of its circumferential ends mated with one end of segment (i), and its other end lifted, thus pivoting the segment until it is adjacent the inside of the skirt near its soffit. A locking bar (not shown) temporarily holds segment (ii) in this position.

As shown in Figure 5, one end of segment (iii) is similarly mated with the other end of segment (i) and lifted sufficiently to allow the other end of segment (iii) to be brought into engagement with the adjacent end of segment (ii), which is lowered from its position adjacent the inside of the skirt, thus forming a complete ring.

This operation can be achieved within the skirt with three identical segments, since the internal skirt diameter is sufficiently larger than the outside diameter of the segment ring, e.g. for a 900 mm. bore segment ring of 60 mm. wall thickness, an internal shield skirt diameter of approximately 1,060 mm. will allow the erection operation within its bore and thus the internal diameter of the skirt is not excessively larger than the external diameter of the segment ring, since the erection of the segments takes place with the invert segment lying adjacent the invert of the skirt, thus taking full advantage of the skirt diameter.

The segment joints, both longitudinal and circumferential, can be coated with a suitable waterproof sealant prior to erection, e.g. bituminous based materials.

When the erection of the segment ring has been achieved, liquid or gas under pressure is forced into the annular tube 23, fabricated of a flexible, impermeable material, and which is situated in the annular void between the outside of the segment ring and the inside of the skirt and thus exerts circumferential pressure on the segments, squeezing the joints and at the same time lifting the whole ring to the approximate centre line of the shield, (see Figures 6 and 7) e.g. a 50 mm. nominal bore tube of about 2 mm. wall thickness operating in an annular ring void of 25 mm. radial width and charged to a pressure of 7 Kg. per sq.cm. and having an area of contact with the periphery of the segment ring of approximately 1,120 sq.cm. will induce a circumferential compression load in the ring of about 1260 Kg., thus tightening the ring and sealing the longitudinal construction joints with a force of about 21 Kg. per centimetre run of joint for a segment ring, 900 mm. bore, 600 mm. in length. The steel locating pin 25 is now removed from the invert segment (i).

The segment ring is then forced back by the rams 21 and jointed with the previously laid ring 26. The shield is also forced forward in the direction of construction, the strata being excavated at the front of the shield and transported to the tunnel entrance for disposal, via the already completed section.

The shield leaves the segment ring in position, which passes through a skirt ring 27, made of suitable resilient material, for example hardwood, which is attached to the skirt of the shield and maintains a radial pressure on the ring during this part of the operation. The annular tube 23 is now deflated or drained.

When the shield has been driven forward one ring length, cement grout 28 or other suitable filling material is forced under pressure between the segment ring and the surrounding material through the pre-formed locating holes of the segments, or through longitudinal holes in the skirt ring, located at the top of the shield.

In order to expedite progress of the work, this material may be of a quick setting nature, for example, high alumina cement grout. This material can be used in batch quantities corresponding in volume to the void between the segment ring and the surrounding material formed by the shield cutting edge, and may be injected by means of compressed air or other suitable type of pump attached to the segment transport vehicle or transported through pipelines from a working shaft.

Alternatively, if a quick setting grout is not used, locking up the segments can be achieved using metal bands or hoops fitted to the outside of the segment ring and suitable tightened, e.g. a hoop of thin steel 30, Figures 1, 8 and 9 of about 15 mm. width and 1 mm. in thickness and of external diameter the same as that of the external diameter of the shield skirt, may be used. The segments are erected as before the steel hoop being previously loosely positioned on the inside of the shield skirt by means of suitable clips 31 axially coincident in position with the three grout holes 32 in the ring units. When the annular tube has been inflated the slack in the hoop is hooked with a suitable tool through one of the upper grout holes and a loop pulled through the holes. A conical wedge 35 is then inserted through

the loop. The wedge is driven home, thus tensioning the hoop pulling it out of the clips and thereby locking the ring circumferentially. The method of operation then continues as before and on setting of the grout the wedges 35 may be withdrawn, the loops cut off and the holes flushed off with a suitable compound. A rebate may be formed in the back of the segment units to accommodate the steel hoop and be of sufficient depth to allow the hoop to be flush with the outside of the ring, thus allowing the whole to pass easily through the shield skirt ring 27.

The three unit segment ring may be of a material which is weak in tension (e.g. concrete) and, whilst showing the advantage of stability during erection, would require reinforcing if subjected to initially unequal external pressures since the ring would act as three two-pin arches, and bending stresses and tensile stresses will be present in the material.

In order to overcome the necessity for such reinforcing, each segment is fabricated with two or more dummy joints 33, Figures 10, 11 and 12 which may consist of 'V' or similarly shaped notches or rebates formed in the axial direction of the ring at the inner and outer faces of the segment in corresponding positions these approximately equi-spaced between the construction joints 34. The rebates are filled with suitable elastic adhesive waterproof compound to maintain watertightness. Such a tunnel lining segment is described and claimed in our copending Application No. 55064/71 (Serial No. 1288393).

Should tensile stresses occur in the unit after erection, due to unequal pressure of the surrounding strata, then cracking will occur at these dummy joints and small rotations will take place both at the dummy joints and at the construction joints and the segment ring will deform as a whole to equalise the external pressure thereon. The spacing of the dummy joints can be calculated such that direct stresses in the material of the segments, due to circumferential stresses and bending stresses caused by approximately uniformly distributed loading by the strata on each sub-segment, are integrated to give resultant stresses within the working stress tolerances of the material, e.g. with concrete zero tensile stress, compressive stress as per the relevant Code of Practice or to other relevant specifications.

The method is also applicable where the tunnel lining is fabricated of inherently flexible material, e.g. glassfibre reinforced resin or of rigid reinforced lining e.g. reinforced concrete.

Furthermore the dowel locking pins 25 may be omitted and it is possible to successfully erect a ring without the pins. Similarly the annular tube 23 may be omitted while still permitting successful tunnel construction.

WHAT WE CLAIM IS:—

1. A method of constructing a lined tunnel which comprises the steps of excavating a short length of tunnel within a shield of internal diameter greater than the external diameter of the lining to be erected, locating a first 120° lining segment within the inner periphery of the shield, engaging one circumferential end of each of two further 120° lining segments with respective circumferential ends of the first segment and pivoting, in turn, said two further segments outwards to bring the other ends of the two further segments into engagement to form a complete ring the axis of which is offset with respect to the axis of the shield, centralising the newly erected ring within the shield, jointing the newly erected ring to the previously erected ring, advancing the shield to a position in which a portion of the newly erected ring extends axially out of the rear end of the shield, injecting a filler material into the annular void between the portion of the newly erected ring projecting from the shield and the surrounding material left by the advancement of the shield whilst the ring is still supported co-axially with the shield by the shield, and then repeating the steps of excavating a short length of tunnel and erecting a lining ring within the shield in its advanced position.

2. The method according to claim 1 in which, in carrying out the step of erecting a ring, the first segment is placed on the bottom of the shield and the other two segments are then placed above the first at opposite circumferential ends thereof to complete the ring, the clearance between the ring and the shield due to the difference in diameter being greater at the top of the ring than at the bottom.

3. The method according to claim 1 or claim 2 in which the first segment is held in position during the erection of the other two segments by a dowel pin engaging in sockets in the segment and the shield.

4. The method according to any one of claims 1 to 3 in which radially inward pressure is applied around the newly erected ring before it is locked to the previously erected ring, to effect circumferential pressure at the joints between the segments.

5. The method according to claim 4 in which the inward pressure is applied by expansion under internal fluid pressure of a flexible annular tube between the shield and the ring.

6. The method according to any one of the preceding claims in which the segments after they have been erected to form a ring are held together by an external circumferential tie.

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5. The method according to claim 4 in which the inward pressure is applied by expansion under internal fluid pressure of a flexible annular tube between the shield and the ring.

6. The method according to any one of the preceding claims in which the segments after they have been erected to form a ring are held together by an external circumferential tie.

* C L M S *

7. The method according to any one of the preceding claims in which the segments are formed with lines or regions of weakness extending in the axial direction of the ring whereby the rings can crack at controlled locations and deform to accommodate unevenly distributed external loads.

8. The method of constructing a lined tunnel substantially as herein described with reference to the accompanying drawings.

9. A lined tunnel when constructed by the method according to any of the preceding claims.

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