

PATENT SPECIFICATION

(11) 1 343 198

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- (21) Application No. 30219/71 (22) Filed 28 June 1971
(31) Convention Application No. 7 009 507
(32) Filed 26 June 1970 in
(33) Netherlands (NL)
(44) Complete Specification published 9 Jan. 1974
(51) International Classification E02D 27/52
(52) Index at acceptance E1H 15
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(54) METHOD OF LAYING A FOUNDATION FOR AN UNDERWATER STRUCTURAL ELEMENT

(71) We, COMBINATIE WESTER-SCHELDE V.O.F. of No. 17, Jaarbeursplein, Utrecht, The Netherlands, a Body Corporate organised and existing under the Laws of The Netherlands, 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:—

This invention relates to a method of laying a foundation for an underwater structural element.

A method for laying a foundation for an underwater structural element is already known in which the space under the structural element is filled up with a foundation material by supplying an aqueous suspension of particles of the foundation material to at least one supply zone. In this method, the suspension is injected through a spout or spouts into one or more supply zones beneath the structural element, so as to fill up firstly the most remote parts of the space under the structural element, and then successively less remote parts and lastly parts near the or each supply zone. Meanwhile water is sucked up from the vicinity of the or each supply zone, the amount of water sucked up being equal to the amount of the suspension supplied to the supply zone or zones. By observing the percentage of foundation material in the water sucked up, the rate of filling of the space beneath the structural element can be estimated. In this known method, it is necessary to provide at each supply zone a corresponding suction pipe and a corresponding delivery pipe provided with a spout, which pipes extend under the structural element and are rotatably mounted therein. To convey the foundation material from each fixed supply zone to places under the structural element remote from said zone and surrounding it, the disposition of the spout on the end of each delivery pipe must be suitably ad-

justed, and the foundation material must be conveyed from each such spout to the required remote locations in the form of a jet in such a manner as to ensure that no cavities in the foundation layer remain unfilled.

Furthermore, owing to the fact that the suspension is discharged from the or each spout in the form of a jet, silt present in the space under the structural element will be mixed in with the suspension and will be deposited together with the foundation material, which will result in a decrease in the supporting capacity of the foundation layer so formed.

This known method can be dangerous, in that owing to its irregular filling and owing to the deposition of silt, the foundation layer may settle more than is expected. Moreover, compensating for this settling by providing an additional layer of foundation material of appropriate thickness is impossible with this known method.

The invention has as its object to provide a method of the kind mentioned in the first paragraph of this specification, in which the above-mentioned disadvantages are avoided or reduced.

With this object in view, there is provided a method of laying a foundation for an underwater structural element, comprising the steps of supporting the structural element so as to provide beneath it a space which is in open communication with spaces on each side of the structural element, delivering an aqueous suspension of particles of the foundation material to at least one supply zone within the space beneath the structural element so as to produce a crater within said supply zone, by forming a dyke of the foundation material in the space beneath the structural element and around the supply zone and subsequently filling up the space around the said crater with foundation material by supplying the suspension to the crater and causing it to

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flow over the edge of the said crater.

With this method the edge of the crater grows gradually so as to form a continuous layer of foundation material. The suspension of particles of foundation material in water flowing over the edge of the crater is heavier than the silt present around the edge of the crater resulting in the suspension driving the silt before it out of the space to be filled without becoming mixed with the silt, owing to the flow velocity of the suspension being low. As a result of this, the foundation layer settles only to a very limited extent which can moreover be calculated.

Furthermore, this settling can be compensated for by supplying additional amounts of the suspension to the supply zone.

In one form of the invention, a plurality of craters is produced under the structural element and the position of the structural element is adjusted by selectively controlling the pressure of and/or the percentage of foundation material in, the suspension supplied to the several craters.

If the structural element is positioned in a trench and if the space in the said trench alongside the structural element is to be filled with foundation material, preferably this space is filled with the foundation material by causing the suspension to flow from the crater over the edge thereof alongside the structural element. In this case, the foundation material displaces completely the silt gathered in the trench.

The hitherto necessary step of removing silt gathered in the trench is preferably therefore not carried out, as this step is superfluous with the method according to the invention.

The invention also includes a structural element having a foundation laid by the method according to the invention.

The invention will now be described by way of example with reference to the accompanying schematic drawings, in which:—

Figure 1 is an elevation of a tunnel being laid by the method according to the invention.

Figure 2 is a section along the line II—II of Figure 1 on an enlarged scale.

Figure 3 is a detail of a longitudinal section along the line III—III of Figure 2.

Figures 4, 5 and 6 are longitudinal sections through a tunnel element as it is being laid during successive stages of the method according to the invention.

Figures 7, 8 and 9 are plan views corresponding respectively to Figures 4, 5 and 6; the space beneath the tunnel element is shown in full lines while the tunnel element itself is indicated in outline by means of a chain-dotted line.

Figure 10 is a cross section through the tunnel element at a still later stage than that of Figures 6 and 9.

Figures 11 and 12 are respectively a plan view and a cross section through a tunnel element being laid by a preferred method according to the invention.

Figures 13 and 14 are cross sections through a structural element being provided with a foundation layer, during successive stages of the procedure.

Figure 15 is a plan view of Figure 13, showing the structural element, a dredging installation and a barge, and the conduits for supplying a sand/water dispersion to the structural element.

Figure 16 is a detail of the structural element of Figures 13 to 15.

Figure 17 is a section through another form of tunnel element.

A sink trench 2 having a trench bottom 3 is dredged in a river bed 1. In this sink trench 2, a series of tunnel elements 4 a—4 e is to be laid with the end elements 4 a and 4 e of the series connected respectively with hollow, open-topped ramp elements 5. As shown in Figure 1, the tunnel element 4 a has already been laid and sand has already been injected under it. The tunnel element 4 b has already been sunk, and rests on temporary supports 6, its end 36 having already been connected to the tunnel element 4 a. To form the foundation for the tunnel element 4 b, sand from a barge 7 is sucked up by a floating suction dredger installation 8, which is positioned clear of the main navigation channel, and is supplied as a sand/water dispersion through a pressure conduit 9, suspension conduits 10 and supply nozzles 11, into a zone 37 within the space 35 beneath the tunnel element 4 b.

It can be seen that this method of laying a foundation does not obstruct the passage of vessels 16 above the tunnel elements 4 b, 4 c and 4 d, while these elements are being laid.

Each supply nozzle 11 is mounted in the bottom 18 of the tunnel element and communicates through a valve 19 and one of the conduits 10 with a suspension conduit 10 b running the entire length of the tunnel element 4 b. This suspension conduit 10 b has, at each end of the tunnel element 4 b, a coupling member 20 b provided with a valve 22 and is adapted to be connected by way of a flexible conduit 21 to the coupling members, e.g. 20 a, of the adjacent tunnel elements. The workers who couple together said coupling members gain access to them through manholes 23 (Fig. 2).

The method is illustrated most clearly in Figures 4—10. At the same time or successively a suspension of sand and water is supplied through the supply nozzles 11 to each of the three supply zones 37 below the bottom of the tunnel element being laid.

Sand settles therefrom firstly as a mound 12 (see Figures 4 and 7). Subsequently a dyke of sand 13 extending up to the bottom 18 of the tunnel element is formed around the supply zone 37 by the continuously supplied sand suspension, thus producing a crater 14. After that the space 35 around and adjacent the crater 14 has been filled with sand, due to the sand suspension flowing out from the crater 14 between the edge thereof and the bottom 18 of the tunnel element. To cause this to happen the supply of the said suspension from the supply nozzle 11 to the crater 14 is continued. The said suspension ultimately flows from the crater 14 through a channel 15 which is formed as a result of the flow of already deposited sand produced by the pressure difference existing between the pressure in the crater 14 and the pressure outside it. The channel 15 extends from the crater 14 in that direction in which the resistance to flow of the already deposited sand is least, that is to say at that side of the crater 14 where the width of the sand table 17, which is formed by the deposited sand engaging the bottom 18 of the tunnel element, is smallest, or in other words, at that side of the crater 14, which most lacks sand for filling the space 35. In this way, larger and larger disc-shaped sand tables 17 are formed around the supply zones 37, as each little heap of sand 55 settles at the end of a channel 15 against the outside of the sand table 17. When the flow resistance along a channel 15 increases due to the extension of this channel 15, the flow velocity in this channel decreases, resulting in an increased settling of the sand from the suspension flowing through this channel 15. This results in an additional increase in the resistance to flow until the required pressure difference for flow to occur along this channel between the crater 14 and the space 35 outside the sand table 17 is greater than the pressure difference required for forming another channel 15 in another direction, in which the radius of the sand table 17 is at that time the smallest.

The operation of uniformly filling the space 35 is continued, even when the sand tables 17 engage each other. As shown in Figure 10, the sink trench 2 alongside the tunnel elements 4 can ultimately be filled with sand by the sand suspension supplied from the crater 14 through the suspension channels 15 as well as the space 35 under the tunnel element 4.

During the formation of the mound 12, the laying of the sand dyke 13, the filling of the space 35 around the craters 14, and during the filling of the space 39 formed by the sink trench 2 alongside the tunnel element 4 the heavy sand/water suspension forces itself under the light weight silt 40,

initially present in the space 35, so driving out this silt 40 before it.

As soon as the presence of sufficient sand is detected in the space 39, for instance by means of gauging rods 29, the valves 19 are shut off. The supply nozzles 11 and the craters 14 into which they debouch are then filled with waterproof cement mortar.

After all the tunnel elements 4 *a*—4 *e* have been laid, the suspension conduits 10 and the valves 19 are disconnected and removed.

The temporary supports 6 consist of foot plates 34 and adjustable legs 33 which stand on the said foot plates 34 and extend through the bottom 18 of the tunnel element 4 *b*, being supported on the said legs 33 through jacks 32.

The supply nozzles 11 are preferably divergent so as to reduce the outlet velocity of the sand/water suspension and thus reduce the volume of the craters 14 formed to as small a volume as possible.

While this method is being carried out, the tunnel elements 4 are maintained on their temporary supports 6 by being suitably ballasted.

The correct positioning of the tunnel element 4 *b* relative to the tunnel element 4 *a* can be achieved in several ways, for instance by reducing the amount of ballast at that corner 41 of a tunnel element 4 which is at a lower level than required (see Figure 12). The suspension flowing over the sand tables 17 will then force the corner 41 of the tunnel element upwards, resulting in the formation of additional sand tables 25. Again the suspension is forced in that direction which most needs additional sand. The inclined space 30 is then gradually filled with sand even though it is asymmetrically disposed relative to the supply zones 37.

The proper positioning of the tunnel elements may, instead of selectively varying the amount of ballast (not shown) in the tunnel element, be effected in an easier way, for instance by selectively controlling the pressure of and/or the percentage of sand in, the suspension supplied to the supply zones 37. The suspension is supplied at a higher pressure and/or with a higher percentage of sand to that supply zone 37 below the tunnel element 4, where the tunnel element has to be lifted, than to the other supply zones 37.

Figures 13—15 show a method for laying a body of sand 42 under water to form a foundation. To effect this, a concrete slab 43 is sunk to the bed 44 of the body of water 45. Supply zones 37 for the sand/water suspension are located at uniform distances from each other and alternately on one side and the other of a plane 46. Each of these supply zones 37 is located beneath a corresponding supply nozzle 11 communicating with one

end of a respective flexible suspension conduit 47. Each of the conduits 47 communicates at its other end by way of a valve 48 with a pressure conduit 49 leading from a suction dredging installation 50 sucking sand from a barge 51.

By selectively controlling the pressure of the suspension supplied to the various supply zones 37, the slab 43 can be kept horizontal while the foundation is being laid. The slab 43 is lifted continuously and gradually by the pressure of the sand/water suspension supplied to the zones beneath it, provided that the weight of the slab 43 is sufficiently low to enable it to be lifted by the suspension pressure.

As shown in Figure 16, a pressure detector 55 for detecting the pressure in the crater 14 and a further pressure detector 52 for detecting the pressure outside the crater 14, are provided in the slab 43 so as to be located over the supply zones 37 and over the space outside the crater 14 respectively. The pressure detector 55 and the further pressure detector 52 or several such further pressure detectors can provide useful information concerning the rate of sand deposition at the space 35.

The bottom 18 of tunnel element 4 does not need to be flat. It is even possible to lay a tunnel element in the form of a round tube 54 (see Figure 17), the bottom and sides of which rest upon a layer of sand 59 in a sink trench 56 by supplying a suspension of sand with water through a supply nozzle 58 to a supply zone 57.

WHAT WE CLAIM IS:—

1. A method of laying a foundation for an underwater structural element, comprising the steps of supporting the structural element so as to provide beneath it a space which is in open communication with spaces on each side of the structural element, delivering an aqueous suspension of particles of the foundation material to at least one supply zone within the space beneath the structural element so as to produce a crater within said supply zone by forming a dyke of the foundation material in the space

beneath the structural element and around the supply zone and subsequently filling up the space around the said crater with foundation material by supplying the suspension to the crater and causing it to flow over the edge of the said crater.

2. A method as claimed in Claim 1, wherein the suspension is delivered to the said crater through the bottom of the said structural element.

3. A method as claimed in Claim 1 or 2, wherein the spaces on each side of the structural element are also filled with the foundation material by causing the suspension to flow from the crater over the edge thereof and into the said spaces on each side of the structural element.

4. A method as claimed in any of the preceding claims, wherein the pressure of the suspension supplied to the crater and/or the pressure thereof in at least one location outside the crater is detected.

5. A method as claimed in any of the preceding claims, wherein a plurality of craters is produced under the structural element and the position of the structural element is adjusted by selectively controlling the pressure of, and/or the percentage of foundation material in, the suspension supplied to the several craters.

6. Method as claimed in any of claims 1 to 4, wherein the structural element is lifted by means of the pressure of the suspension supplied to the supply zone.

7. An underwater structural element having a foundation laid by the method as claimed in any of the preceding claims.

8. A method of laying a foundation for an underwater structural element, substantially as hereinbefore described with reference to the accompanying drawings.

9. An underwater structural element, substantially as hereinbefore described with reference to the accompanying drawings.

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beneath the structural element and around the supply zone and subsequently filling up the space around the said crater with foundation material by supplying the suspension to the crater and causing it to flow over the edge of the said crater.

2. A method as claimed in Claim 1, wherein the suspension is delivered to the said crater through the bottom of the said structural element.

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