

12

-1-

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METHOD OF BUILDING A CAVITY
STRUCTURE IN AN EMBANKMENT

(13)

- 2 -

This invention relates to a method of building a cavity structure in an embankment.

When a new road such as a highway is constructed to intersect already existing roads, rivers, water-ways or the like, the method generally employed has been to build an embankment over the existing road or the like with the new road constructed on the embankment in a two level crossing. It is necessary to provide a cavity structure transversely through the embankment so as to provide a passage for retaining the existing road or the like. The structure to be thus built in the embankment includes specifically a concrete-made tunnel, substructures for a bridge, a box structure or the like, and the peripheral portions of the structure in the embankment must be sufficiently stabilized so as to prevent its side walls and ceiling from being collapsed or broken.

Referring more specifically to this conventionally employed method with reference to Fig. 1, when a new road NR is constructed, a buried structure SB such as a tunnel is initially built from reinforced concrete or the like over each of, for example, an existing road OR and a water-way WR, and thereafter an embankment is constructed over the structures SB for the new road construction. However, in order to transport embanking materials to the site of the new road, it is necessary to provide preparatory construction roads PR leading to respective parts of the site between the existing road OR and water-way WR and beyond the former.

According to this method, however, the embanking work for the new road construction can be performed only after sufficient hardening of the concrete material of the structure SB because, each time the new road
5 crosses each existing road or the like, a structure SB must be built prior to the new road construction. It has therefore been impossible to construct the new road continuously but only intermittently so that the construction period is prolonged. Moreover, the
10 provision of construction roads PR in order to avoid prolongation of the construction period caused when the thus intermittently made new road is utilized for the transportation of embanking material increases costs still further and is even occasionally
15 impossible for geographic reasons.

The present invention aims to provide a method of building a structure in an embankment which allows a continuous construction of a new road without any interruption so as to be achievable even when the new
20 road crosses existing roads, water-ways and the like.

Another aim of the present invention is to provide a method of building a structure in an embankment which makes it possible to utilize effectively the new road being constructed to perform the embanking work for
25 its crossing with existing roads and the like without requiring any provision of construction roads for such work.

(15)

- 4 -

Accordingly, the present invention provides a method of building a cavity structure in an embankment during its embanking work at a position corresponding to an existing road, water-way or the like in constructing a
5 new road across said existing road or the like with said embankment, in which portions inside the embankment which are to form side wall layers of a later excavated cavity for the structure are embanked simultaneously with remaining portions of the
10 embankment, a plurality of vertically spaced nets being buried so as to intersect substantially horizontally sliding surfaces appearing in the layers upon excavation of the cavity, in which an upper ceiling portion of the later excavated cavity is
15 prestressed during embankment work by means of at least crushed stone filling between supporting plates which are buried respectively above each of the side wall portions and coupled by tensioned wires and in which, after completion of the embanking work, the
20 cavity is excavated by removing embanked material in a zone surrounded by the side layer portions and prestressed ceiling portion, so that the structure can be built within the cavity with the side layers and ceiling layer stably maintained and prevented from
25 collapsing by the nets buried in the layers.

The invention will now be further described, by way of example, with reference to the drawings, in which:-

Fig. 1 is a schematic diagram for explaining a conventional method of constructing a new road
30 transversing existing roads and the like;

Fig. 2 is a fragmentary cross-section of an embankment specifically at its portion forming side wall layers of a cavity structure to be built in an embankment made according to the method of the present invention 5 for new road construction;

Fig. 3 is a fragmentary cross section of an embankment made according to the method of the present invention and showing its entire height for showing the state in which the side wall layers of Fig. 2 and a prestressed 10 upper ceiling part are made for the cavity structure later excavated;

Fig. 4 is a fragmentary plan view of the prestressed ceiling part of Fig. 3, showing respective layers and materials forming the part with upper positioned ones 15 of each of them removed sequentially from the left end showing the bottom to the right end showing the top; and

Fig. 5 is a fragmentary cross-section of the embankment of Fig. 3 but in its state in which a 20 tunnel has been excavated by removing embanked materials in a zone defined by the side wall and upper ceiling layers and foundation ground for the cavity structure in the embankment.

Reference will first be made to Fig. 2 of the drawings 25 in which a buried net 12 made preferably of polyethylene threads is initially placed horizontally on a foundation ground 11 at the side of making the embankment substantially over the entire surface of

(17)

- 6 -

the site. For the net 12, the polyethylene threads of a tensile elastic modulus of 7.0 Kg/cm^2 are meshed to provide a grid of 2.5 to 3.0 cm and to have an allowable tensile-resisting stress of about 1.000 5 Kg/m.

In order to form the respective two opposing side wall portions of an intended structure such as a tunnel of, for example, rectangular cross-section, as spaced horizontally and erected on the ground 11 inside the 10 embankment, a side wall layer 13 of cement for each side wall of the tunnel and a side layer 14 of soil on each opposite outer side of the cement side wall layers 13 are built up during the embanking work on the initially placed buried net 12, with a plurality 15 of vertically spaced nets 15 being horizontally disposed and embedded in the layers 13 and 14. The nets 15 are vertically spaced at intervals of preferably 10-15cm and are made of polyethylene threads of a smaller size than that of the buried net 20 12 so as to have an allowable tensile-resisting stress of about 500 Kg/m. Further, a crushed stone layer 16 preferably of a width substantially corresponding to the total width of each of the side cement and soil layers 13 and 14 is also built up on the outer side of 25 each soil layer 14 while embanking materials are built up on the inner and outer sides of both side wall portions thus being erected with the respective layers 13, 14 and 16. After the cement and soil side wall layers 13 and 14, with the nets 15 embedded therein, 30 and the crushed stone layers 16 as well as the embankment have been built up to be 40 to 60cm high, a

(18)

further net 12 is placed thereon horizontally. Such embanking and wall-forming work is repeated while providing a sufficient rolling compaction, until a required height of the tunnel or the like structure is reached.

Further, referring to Figs. 3 and 4, after the upper surface of the embankment having the required height for the structure is sufficiently rolled and flattened, a still further net 12 is placed on the flattened embankment and then a reinforcing sheet 17 preferably made of plastic material and having a considerable thickness is placed immediately on the uppermost net 12. In this case, the buried net 12 has an area or size substantially covering the entire surface of the ground, whereas the reinforcing sheet 17 is set to have an area or size nearly corresponding to the upper surface of the structure to be built.

Above the buried net 12 and reinforcing sheet 17, supporting plates 18 preferably made of steel are disposed with their flat surfaces opposed to each other so that the plates are positioned respectively slightly outside of the outermost crushed stone layers 16 of both side wall portions. Each supporting plate 18 may be provided with a horizontally-extending skirt portion or may be temporarily mounted on a separate holding plate (not shown) which extends horizontally. Further, soil retaining plates 19 may be disposed to extend between the opposed supporting plates 18 so that the plates 18 may be stably erected. Next, a comparatively small amount of crushed stone 20 is

19

- 8 -

flatly placed between the supporting plates 18. Then, a net 12 is spread over the crushed stone layer between the plates 18, prestressing steel wires 21 are hung across the opposing supporting plates 18 and 5 secured to the plates at both ends by any suitable means such as welding or bolt-and-nut attachments passed through the plates. The steel wires 21 should preferably be made of rust resistive material and a plurality of them are arranged in horizontal and 10 mutually parallel relation.

Next, a layer of the crushed stone 20 and a small amount of fine grained sands are placed between the supporting plates 18 and over the already placed crushed stone layer, net 12 and prestressing wires, 15 and next a further net 12 is provided at an intermediate level of the height of the supporting plates 18. Above this further net 12, as above, further prestressing steel wires 21 are secured between the supporting plates 18 in the same manner, a 20 further layer of the crushed stone 20 and small amount of fine grained sands is formed over the last-mentioned net 12 and steel wires 21, a still further net 12 is placed on the further crushed stone layer between the supporting plates 18, and an additional 25 layer of crushed stone 20 is formed up to the top end level of the plates 18. A further reinforcement sheet 17 is placed at the top level of the thus formed crushed stone layers filling between the opposed supporting plates 18 while the embanking work for the 30 entire embankment is performed, and sufficient rolling compaction is repeated with respect to the embanked

materials and crushed stone layers 20 between the supporting plates 18. The embanking work is thereafter continued while providing rolling compaction and placing therein a suitable number of 5 vertically spaced buried nets 12 covering the entire surface of the embanked materials.

During this continued embanking work and preferably when the height of the embankment reaches a level between 0.5 and 1.0m above the reinforcement sheet 17 10 on the crushed stone layers 20 so that the ground pressure of embanked material onto the layers 20 will be remarkable, a prestress is applied to the steel wires 21 so that they are tightened and the entire body of the crushed stone layers 20 will be a 15 prestressed ceiling part of the intended tunnel or the like structure. For this purpose, the securing at one end of the wires to the supporting plate 18 on one side is initially made in a temporary manner, a proper working space is left outside the particular plate 18 20 for disposing therein centre-hole jacks (not shown) to couple them to the temporarily secured ends of the wires 21, and the jacks are driven to have the wires firmly secured in tightened state to the plate 18 by means of the welding or bolt-and-nut, with a 25 sufficient prestress provided. During this prestressing operation the fine grained sand mixed with the crushed stone 20 to fill between the supporting plates 18 will act to provide a proper sliding effect to the steel wires 21 so that the wires 30 can be smoothly tightened while not subjected to any substantial friction of respective pieces of the crushed stone 20.

When the prestressing operation is completed, the jacks are removed and the working space is filled with embanking material which is roll-compacted to the level already reached, and the embanking work is
5 further continued with any further buried net or nets 12 as required until the required height of the embankment is reached while repeating the rolling compaction. It will be understood to those skilled in the art that, in the thus built embankment, the
10 prestressed ceiling part mainly comprising the crushed stone layers 20 between the supporting plates 18 functions substantially as a sort of solid flat plate which bridges across the crushed stone layers 16 erected below the layers 20 to act as supporting
15 walls.

After the completion of the foregoing embanking work, the zone defined by the foundation ground 11, the inner walls of the cement side wall layers 13 and the bottom reinforcement sheet 17 is excavated while
20 cutting and removing the buried nets 12 with the embanked materials within the zone to form a cavity 22 as in Fig. 5. During the formation of the cavity 22, the embanked materials tend to slide along such an imaginary sliding surface extending diagonally through
25 the soil layers 14 and cement layers 13 as shown by dotted lines SL in Figs. 3 and 5 so that the side walls of the cavity may be collapsed. According to the present invention, however, the peripheral portions of the cavity 22 in the embankment are
30 sufficiently strengthened and any collapse of the side walls of the cavity will not take place, because of

the provision of the buried nets 12 and 15 which co-operate with the cement layers 13, soil layers 14, crushed stone layers 16 and embanked materials. More particularly, the buried nets 12 and nets 15 present 5 in the soil layers 14 and passing through the sliding surface SL horizontally are subjected to a tensile force due to a sliding force of the soil generated along the sliding surface SL. When this tensile force is imparted to the nets, the soil compacted within 10 respective net meshes so as to form on a microscopic scale a column in each mesh receives a shearing force of the net-forming threads and this shearing force transmitted to the respective columns of soil cancels the tensile force, whereby the entire soil on the 15 sliding surface SL can be stably retained. In other words, when the total strength of the respective nets and soil columns in the nets is greater than the sliding force, the nets and soil columns will not behave themselves independently of each other, so that 20 the embanked soil in the layers 14 along the sliding surface SL can be reliably stably retained. Further, the buried nets 12 function not only to stabilize the sliding surface SL as in the foregoing but also to prevent the crushed stone layers 16 from being 25 horizontally displaced, so that the horizontal shearing force of the nets can be increased and thus the stabilization of the side walls can be also increased.

It will be easily understood by those skilled in the 30 art that the function of the buried nets 12 in the side wall portions as referred to above can apply substantially similarly to the upper ceiling portion

comprising mainly the crushed stone layers 20 between the supporting plates 18, in which the buried nets 12 and crushed stone layers 20 can be made integral with each other and also with surrounding embanked materials and, as the layers 20 are prestressed, the ceiling portion can be made firm as if it were a solid block, whereby the peripheral parts of the cavity 22 can have a strength substantially equal to or even higher than that of any conventional structure preliminarily built. In addition, after the excavation of the cavity 22, the cement layers 13 and the lower part of the prestressed ceiling portion between the supporting plates 18 may be utilized to form a permanent retaining structure surrounding the cavity 22 with high durability, while a proper lining wall material may be applied on the inner wall of the structure, if required.

Further, the present invention can be modified in such various manners as follows:-

20 When, for example, a certain amount of foamed styrol fragments is mixed with the crushed stone 20 and fine grained sand in forming the prestressed ceiling portion, any displacement of the crushed stone 20 can be smoothly prevented and thus the crushed stone can be favourably prevented from being unstabilized and collapsed. Further, when a foamed styrol layer is provided in the vicinity of the periphery of the cavity 22, vibrations therein caused by earthquakes or the like can be absorbed by such layer to further stabilize the periphery.

While in the illustrated embodiment the portions forming the side walls of the cavity 22 are shown to include the cement layers, the portions may even comprise only the layers of soil, in which event, too, 5 the cavity 22 can be sufficiently stabilized and, if necessary, cement may be applied to the upper and side surfaces of the cavity 22 after the cavity has been excavated. Further, the number of buried nets 12 and 15 and steel wires 21 may be increased or decreased 10 depending on the region in the embankment and the like conditions of the construction site. Although the prestressed ceiling structure between the supporting plates 18 is preferably symmetrical with respect to the buried net 12 positioned at the middle level of 15 the supporting plates 18, the structure may be asymmetric. Furthermore, although as shown in the drawings, the prestressing steel wires 21 have been arranged in two stages, they may be provided in only one or more than two stages. Moreover, one or both of 20 the reinforcing sheets 17 provided above and below the prestressed ceiling structure may be replaced by an iron plate, rust resisting steel plate, concrete plate or like rigid member.

According to the method of the present invention as 25 has been disclosed, the embanked layer structure above the cavity formed in the embankment can sufficiently endure the weight of running vehicles during the continuous construction of the embankment or the new road extended, trucks for transporting embanking 30 materials and so on can be allowed to run immediately on the embanked new road having the formed cavity and



- 14 -

thus it becomes unnecessary to provide any construction road for the new road construction. In addition, since it is unnecessary to wait for completion of the hollow structure as in the prior art, the new road can be extended even before excavation of the cavity, whereby the construction period can be reduced to a large extent and the construction cost can be economized.

The invention is not restricted to the above-described embodiment but variations and modifications may be made without departing from the scope of the invention as defined by the appended claims.

26

CLAIMS

1. A method of building a cavity structure in an embankment during its embanking work at a position corresponding to an existing road, water-way or the like in constructing a new road across said existing road or the like with said embankment, in which portions inside the embankment which are to form side wall layers of a later excavated cavity for the structure are embanked simultaneously with remaining portions of the embankment, a plurality of vertically spaced nets being buried so as to intersect substantially horizontally sliding surfaces appearing in the layers upon excavation of the cavity, in which an upper ceiling portion of the later excavated cavity is prestressed during embankment work by means of at least crushed stone filling between supporting plates which are buried respectively above each of the side wall portions and coupled by tensioned wires and in which, after completion of the embanking work, the cavity is excavated by removing embanked material in a zone surrounded by the side layer portions and prestressed ceiling portion, so that the structure can be built within the cavity with the side layers and ceiling layer stably maintained and prevented from collapsing by the nets buried in the layers.

2. A method according to claim 1, wherein each side wall portion comprises a cement layer erected inside a soil layer and a crushed stone layer erected outside the soil layer.





3. A method according to claim 2, wherein a plurality of additional nets, of smaller size than the first-mentioned nets, are buried in a vertically spaced manner in the cement layers and said layers of 5 the side wall portions.

4. A method according to any preceding claim, wherein fragments of foamed styrol are mixed with the crushed stone filling between the supporting plates and wherein reinforcing sheets are provided on the 10 bottom and top surfaces of said crushed stone layers.

5. A method according to any preceding claim, wherein a buried net is positioned at the middle level of said supporting plates between layers of the crushed stone filling and wherein other buried nets 15 and reinforcing sheets are provided in symmetrical relation to said buried net.

6. A method of building a cavity structure substantially as described herein with reference to Figs. 2 to 5 of the drawings.

