

WATERPROOF CURTAINS AT ENDS OF UNDERWATER CHANNEL FOUNDATION PIT ALONG WATER BANKS

TECHNICAL FIELD

The present invention relates to the field of construction engineering and, in particular, to a waterproof curtain at ends of underwater channel foundation pit along water banks.

BACKGROUND

Compared with waterproof curtains for foundation pit in soil strata, the construction of waterproof curtains for foundation pit in water, such as those for underwater channels traversing under rivers, is more challenging and very prone to seepage and water leaks, as well as other potential safety hazards. Seepage is a particularly significant problem for ends of underwater channel foundation pit and more frequently takes place, in particular, in foundation pit along rivers in the southern region with abundant groundwater and a relatively high water level. For an underwater channel foundation pit traversing under a river, an open-cut method is typically employed to excavate an underground channel that traverses under the river. In this process, a cofferdam is constructed for waterproof prior to the excavation of the cross-river underwater channel. Existing waterproof curtains for foundation pit include high-pressure jet grouting piles, which are underneath a base slab in the underwater channel foundation pit in order to provide a water resistant effect to the underwater channel foundation pit. After the construction of a revetment is complete, due to foundation settlement, the high-pressure jet grouting piles may be detached from the base slab in the underwater channel foundation pit, creating a seepage channel, through which water from the river may seep into the underwater channel foundation pit. Therefore, anti-

seepage of waterproof curtains for underwater channel foundation pits is an urgent issue to be addressed by those skilled in the art.

SUMMARY OF THE INVENTION

The technical problem to be solved by the present invention is to provide a waterproof curtain at ends of underwater channel foundation pit along water banks, so as to overcome the problem related to seepage of underwater channel foundation pits.

In order to solve the above technical problem, the present invention provides a waterproof curtain at ends of an underwater channel foundation pit along water banks, comprising: a first high-pressure jet grouting pile and a second high-pressure jet grouting pile, which are horizontally joined together beneath a base slab at the ends of the underwater channel foundation pit along the water banks; and a third high-pressure jet grouting pile, which is situated above the base slab in the underwater channel foundation pit and vertically joined to the first high-pressure jet grouting pile, wherein the second high-pressure jet grouting pile, the third high-pressure jet grouting pile and the first high-pressure jet grouting pile therebelow are situated internal to foundation pit soldier piles at the ends of the underwater channel foundation pit along the water banks.

Further, in the waterproof curtain at ends of an underwater channel foundation pit along water banks according to the present invention, the first high-pressure jet grouting pile is joined to the third high-pressure jet grouting pile by a dense yellow sand backfill layer and a load transfer plain concrete band.

Further, in the waterproof curtain at ends of an underwater channel foundation pit along water banks according to the present invention, the third high-pressure jet grouting pile comprises a lower pile segment and an upper pile segment, which are joined together by a joint slab situated between an external revetment and the lower and upper pile segments.

Further, in the waterproof curtain at ends of an underwater channel foundation pit

along water banks according to the present invention, a depth of the second high-pressure jet grouting pile is smaller than a depth of the first high-pressure jet pile.

Further, in the waterproof curtain at ends of an underwater channel foundation pit along water banks according to the present invention, a density of the second high-pressure jet grouting pile is greater than a density of the first high-pressure jet grouting pile, and wherein the second high-pressure jet grouting pile is formed by compaction grouting.

Further, in the waterproof curtain at ends of an underwater channel foundation pit along water banks according to the present invention, the second high-pressure jet grouting pile is situated internal to the first high-pressure jet grouting pile, and wherein the first high-pressure jet grouting pile and the third high-pressure jet grouting pile are situated between side walls of the underwater channel foundation pit and the foundation pit soldier piles.

Further, in the waterproof curtain at ends of an underwater channel foundation pit along water banks according to the present invention, the third high-pressure jet grouting pile is at a same level as the ground level.

Further, in the waterproof curtain at ends of an underwater channel foundation pit along water banks according to the present invention, the foundation pit soldier piles comprise a fourth high-pressure jet grouting pile and a bored pile, both arranged in the underwater channel foundation pit.

Further, in the waterproof curtain at ends of an underwater channel foundation pit along water banks according to the present invention, a contour line of the fourth high-pressure jet grouting pile is lower than a contour line of the third high-pressure jet grouting pile and is at a same level as an external revetment where the ends of the underwater channel foundation pit along the water banks is seated.

Further, in the waterproof curtain at ends of an underwater channel foundation pit along water banks according to the present invention, the second high-pressure jet

grouting pile, the third high-pressure jet grouting pile and the first high-pressure jet grouting pile therebelow are arranged along both lengthwise and widthwise directions of the ends of the underwater channel foundation pit along the water banks so as to form a structure that is enclosed on three sides.

Compared with the prior art, in the waterproof curtain for an underwater channel foundation pit according to the present invention, the horizontally joined first high-pressure jet grouting piles and second high-pressure jet grouting piles make up a pile foundation with a contact area below the base slab of the underwater channel foundation pit, resulting in higher structural stability of the base slab and the underlying pile foundation and thus preventing the creation of a seepage channel resulting from detachment of the first high-pressure jet grouting piles from the base slab of the underwater channel foundation pit. When settlement of the first high-pressure jet grouting piles takes place, the third high-pressure jet grouting piles vertically joined to the first high-pressure jet grouting piles will settle synchronously therewith. As a result, the third high-pressure jet grouting piles will displace downward the same amount as the displacement of the first high-pressure jet grouting piles and thus fill the gaps between the first high-pressure jet grouting piles and the base slab of the underwater channel foundation pit. In this way, the potential safety hazard of a seepage channel present around the base slab of the underwater channel foundation pit can be addressed, avoiding seepage of the underwater channel foundation pit. According to the present invention, arranging the second high-pressure jet grouting piles, the third high-pressure jet grouting piles and the first high-pressure jet grouting piles therebelow internal to the foundation pit soldier piles at ends of underwater channel foundation pit along water banks reinforces the water resistant effect provided by the second high-pressure jet grouting piles, the third high-pressure jet grouting piles and the first high-pressure jet grouting piles therebelow to the foundation pit soldier piles.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic top view of the structure of a waterproof curtain according to an embodiment of the present invention;

Fig. 2 is a schematic top view of the structure of the waterproof curtain at ends of an underwater channel foundation pit along water banks according to an embodiment of the present invention;

Fig. 3 is a schematic cutaway view of the structure of the waterproof curtain at ends of an underwater channel foundation pit along water banks according to an embodiment of the present invention;

Fig. 4 is a schematic partial cutaway view of the structure of the waterproof curtain at ends of an underwater channel foundation pit along water banks according to an embodiment of the present invention; and

Fig. 5 is a schematic partial cutaway view of the structure of the waterproof curtain at ends of an underwater channel foundation pit along water banks, according to an embodiment of the present invention, as viewed from another side.

In these figures, 100 denotes an underwater channel; 110, a foundation pit; 111, a base slab; 120, bored piles; 130, high-pressure jet grouting piles; 140, a side wall; 150, an external revetment; 160, an end; 170, a box revetment; 171, a temporary partition wall; 180, the ground level; 200, a waterproof curtain; 210, first high-pressure jet grouting piles; 220, second high-pressure jet grouting piles; 230, third high-pressure jet grouting piles; 231, lower pile segments; 232, upper pile segments; 233, a joint slab; 240, a dense yellow sand backfill layer; 250, a load transfer plain concrete band; 300, a shore line; and 400, a basement exterior wall.

DETAILED DESCRIPTION

The present invention will be described in detail with reference to the accompanying drawings.

Referring to Figs. 1 to 5, embodiments of the present invention provide a waterproof curtain 200 for an underwater channel foundation pit, including: first high-pressure jet grouting piles 210 and second high-pressure jet grouting piles 220, which are horizontally joined to each other beneath a base slab 111 at the ends 160 of the underwater channel foundation pit 110 along the water banks; and third high-pressure jet grouting piles 230, which are situated above the base slab 111 of the underwater channel foundation pit 110 and vertically joined to the first high-pressure jet grouting piles 210. The second high-pressure jet grouting piles 220, the third high-pressure jet grouting piles 230 and the first high-pressure jet grouting piles 210 therebelow are situated internal to foundation pit soldier piles at the ends 160 of the underwater channel foundation pit 110 along the water banks. The foundation pit soldier piles include, but are not limited to, fourth high-pressure jet grouting piles 130 and bored piles 120 in the underwater channel foundation pit 110. Here, the ends 160 is in positional correspondence with the underwater channel foundation pit 110 external to a shore line 300.

According to embodiments of the present invention, the first high-pressure jet grouting piles 210, the third high-pressure jet grouting piles 230 and the fourth high-pressure jet grouting piles 130 include, but are not limited to, a double row of high-pressure jet grouting piles ($\varnothing 800@500$), which are stronger and more stable when used as water resistant piles. The second high-pressure jet grouting piles 220 include, but are not limited to, a double row of high-pressure jet grouting piles ($\varnothing 700@500$) with a cement content of 25% for reinforcing the foundation pit. Bored piles 120 between the third high-pressure jet grouting piles 230 and the fourth high-pressure jet grouting piles 130 include, but are not limited to, piles ($\varnothing 800 \times 22500@1000$). Bored piles situated at the base slab 111 may be implemented as piles ($\varnothing 1000 \times 35000$).

Referring to Figs. 3 to 5, in order to achieve a vertical engagement between the third high-pressure jet grouting piles 230 and the first high-pressure jet grouting piles

210, according to an embodiment of the present invention, in the waterproof curtain 200 at the ends 160 of the underwater channel foundation pit 110 along the water banks, the third high-pressure jet grouting piles 230 are joined to the first high-pressure jet grouting piles 210 by a dense yellow sand backfill layer 240 and a load transfer plain concrete band 250.

Referring to Figs. 3 and 4, according to an embodiment of the present invention, in the waterproof curtain 200 at the ends 160 of the underwater channel foundation pit 110 along the water banks, the third high-pressure jet grouting piles 230 include lower pile segments 231 and upper pile segments 232, which are joined together by a joint slab 233 situated between an external revetment 150 and the lower and upper pile segments 231, 232. The upper pile segments 232 of the external revetment 150 are grouted above the lower pile segments 231 after soil backfilling until they reach the ground level 180. That is, the third high-pressure jet grouting piles 230 are as high as the ground level 180.

Referring to Figs. 3 to 5, according to an embodiment of the present invention, in the waterproof curtain 200 at the ends 160 of the underwater channel foundation pit 110 along the water banks, a depth of the second high-pressure jet grouting piles 220 is smaller than a depth of the first high-pressure jet grouting piles.

Referring to Figs. 3 to 5, according to an embodiment of the present invention, in the waterproof curtain 200 at the ends 160 of the underwater channel foundation pit 110 along the water banks, a density of the second high-pressure jet grouting piles 220 is greater than a density of the first high-pressure jet grouting pile 210, and the second high-pressure jet grouting piles 220 are formed by compaction grouting. The density of the second high-pressure jet grouting piles 220 that is greater than the density of the first high-pressure jet grouting piles 210 allows the second high-pressure jet grouting piles 220 to be more reliably joined to the first high-pressure jet grouting piles 210 and more structurally stable. Use of compaction grouting enables a higher density below the

base slab 111, thus avoiding synchronously settlement of the first high-pressure jet grouting piles 210 and the second high-pressure jet grouting piles 220.

Referring to Figs. 1 to 2, according to an embodiment of the present invention, in the waterproof curtain 200 at the ends 160 of the underwater channel foundation pit 110 along the water banks, the second high-pressure jet grouting piles 220 are situated internal to the first high-pressure jet grouting piles 210, and the first high-pressure jet grouting piles 210 and the third high-pressure jet grouting piles 230 are situated between side walls 140 of the underwater channel foundation pit 110 and the foundation pit soldier piles. According to this embodiment of the present invention, adding the third high-pressure jet grouting piles 230 vertically joined to the first high-pressure jet grouting piles 210 between the conventional foundation pit soldier piles and side walls 140 can enhance water resistance of the ends 160 of the underwater channel foundation pit and impart improved water-resistant capabilities, thus overcoming or eliminating the problem about seepage of the ends 160 of the underwater channel foundation pit.

Referring to Figs. 3 to 5, according to an embodiment of the present invention, in the waterproof curtain 200 at the ends 160 of the underwater channel foundation pit 110 along the water banks, a contour line of the fourth high-pressure jet grouting piles 130 is lower than a contour line of the third high-pressure jet grouting piles 230 and is at a same level as the external revetment 160 where the ends 160 of the underwater tunnel excavation 110 along the water banks is seated.

Referring to Figs. 1 to 2, according to an embodiment of the present invention, in the waterproof curtain 200 at the ends 160 of the underwater channel foundation pit 110 along the water banks, the second high-pressure jet grouting piles 220, the third high-pressure jet grouting piles 230 and the first high-pressure jet grouting piles 210 therebelow are arranged along both lengthwise and widthwise directions of the ends 160 of the underwater channel foundation pit 110 along the water banks so as to form a structure that is enclosed on three sides. Thus, according to this embodiment of the

present invention, the waterproof curtain 200 can prevent seepage on the three sides of the ends 160 of the underwater channel foundation pit 110 along the water banks, thus providing a better water resistant effect.

According to an embodiment of the present invention, for applications without special requirements, the third high-pressure jet grouting piles 230 and the first high-pressure jet grouting piles 210 therebelow are desirably formed of a 42.5 or higher grade ordinary Portland cement. A lower water-cement ratio can result in higher strength of a high-pressure jet grouting foundation. Typically, the ratio is between 0.8 and 2.0. Unconfined compressive strength of cemented soil in the piles at 28 days shall not be lower than 2.5 Mpa, and a compressive modulus of the piles shall not be lower than 80-90 Mpa.

In the waterproof curtain 200 for the underwater channel foundation pit 110 provided in embodiments of the present invention, the horizontally joined first high-pressure jet grouting piles 210 and second high-pressure jet grouting piles 220 make up a pile foundation with a contact area below the base slab 111 of the underwater channel foundation pit 110, resulting in higher structural stability of the base slab 111 and the underlying pile foundation and thus preventing the creation of a seepage channel resulting from detachment of the first high-pressure jet grouting piles 210 from the base slab 111 of the underwater channel foundation pit 110. When settlement of the first high-pressure jet grouting piles 210 takes place, the third high-pressure jet grouting piles 230 vertically joined to the first high-pressure jet grouting piles 210 will settle synchronously therewith. As a result, the third high-pressure jet grouting piles 230 will displace downward the same amount as the displacement of the first high-pressure jet grouting piles 210 and thus fill the gaps between the first high-pressure jet grouting piles and the base slab of the underwater channel foundation pit. In this way, the potential safety hazard of a seepage channel present around the base slab 111 of the underwater channel foundation pit 110 can be addressed, avoiding seepage of the

underwater channel foundation pit 110. According to embodiments of the present invention, arranging the second high-pressure jet grouting piles 220, the third high-pressure jet grouting piles 230 and the first high-pressure jet grouting piles 210 therebelow internal to the foundation pit soldier piles at ends 160 of the underwater channel foundation pit 110 along the water banks can reinforce the water resistant effect provided by the second high-pressure jet grouting piles 220, the third high-pressure jet grouting piles 230 and the first high-pressure jet grouting piles 210 therebelow to the foundation pit soldier piles. That is, according to embodiments of the present invention, water resistance can be achieved by the high-pressure jet grouting piles. In order to additionally improve the water resistant effect, rubber tapes may be provided at structural joints as water stops.

The high-pressure jet grouting piles are continuously connected cement-reinforced columnar piles formed by jetting grout into soil so that soil is peeled off and mixed with the jetted grout. This is advantageous in a small construction site required, low vibration, low noise, etc. and suitable for handling foundation soil such as mud, muddy soil, flow plastic, soft plastic or plastic cohesive soil, silty soil, sandy soil, yellow soil, plain fill and gravel soil. Consolidated bodies produced by the high-pressure jet grouting technique have desirable toughness and good anti-seepage performance.

Referring to Figs. 3 to 5, in order to enhance stability of the underwater channel, according to embodiments of the present invention, a box revetment 170 is provided above the base slab 111, and a temporary partition wall 171 is provided where the box revetment 170 interfaces with the third high-pressure jet grouting piles 230. Of course, the box revetment 170 may be joined to the third high-pressure jet grouting piles 230 by a ribbed slab, resulting in increased joint reliability.

According to embodiments of the present invention, the third high-pressure jet grouting piles 230 may be replaced by Lassen steel sheet piles.

Waterproof curtains according to embodiments of the present invention are

suitable for use in underwater channels crossing rivers, especially large rivers. Referring to Fig. 1, the waterproof curtain 200 according to embodiments of the present invention can be used to prevent seepage to a basement exterior wall 400 and to a basement garage constructed behind it.

The present invention is not limited to the above specific embodiments, and any variations and modifications made by those skilled in the art on the basis of the above teachings fall within the scope of the invention as defined by the appended claims.

CLAIMS

1. A waterproof curtain at ends of an underwater channel foundation pit along water banks, comprising: a first high-pressure jet grouting pile and a second high-pressure jet grouting pile, which are horizontally joined together beneath a base slab at the ends of the underwater channel foundation pit along the water banks; and a third high-pressure jet grouting pile, which is situated above the base slab in the underwater channel foundation pit and vertically joined to the first high-pressure jet grouting pile, wherein the second high-pressure jet grouting pile, the third high-pressure jet grouting pile and the first high-pressure jet grouting pile therebelow are situated internal to foundation pit soldier piles at the ends of the underwater channel foundation pit along the water banks.

2. The waterproof curtain at ends of an underwater channel foundation pit along water banks according to claim 1, wherein the first high-pressure jet grouting pile is joined to the third high-pressure jet grouting pile by a dense yellow sand backfill layer and a load transfer plain concrete band.

3. The waterproof curtain at ends of an underwater channel foundation pit along water banks according to claim 1, wherein the third high-pressure jet grouting pile comprises a lower pile segment and an upper pile segment, which are joined together by a joint slab situated between an external revetment and the lower and upper pile segments.

4. The waterproof curtain at ends of an underwater channel foundation pit along water banks according to claim 1, wherein a depth of the second high-pressure jet grouting pile is smaller than a depth of the first high-pressure jet pile.

5. The waterproof curtain at ends of an underwater channel foundation pit along water banks according to claim 1, wherein a density of the second high-pressure jet grouting pile is greater than a density of the first high-pressure jet grouting pile, and wherein the second high-pressure jet grouting pile is formed by compaction grouting.

6. The waterproof curtain at ends of an underwater channel foundation pit along water banks according to claim 1, wherein the second high-pressure jet grouting pile is situated internal to the first high-pressure jet grouting pile, and wherein the first high-pressure jet grouting pile and the third high-pressure jet grouting pile are situated between side walls of the underwater channel foundation pit and the foundation pit soldier piles.

7. The waterproof curtain at ends of an underwater channel foundation pit along water banks according to claim 1, wherein the third high-pressure jet grouting pile is at a same level as the ground level.

8. The waterproof curtain at ends of an underwater channel foundation pit along water banks according to claim 1, wherein the foundation pit soldier piles comprise a fourth high-pressure jet grouting pile and a bored pile, both arranged in the underwater channel foundation pit.

9. The waterproof curtain at ends of an underwater channel foundation pit along water banks according to claim 8, wherein a contour line of the fourth high-pressure jet grouting pile is lower than a contour line of the third high-pressure jet grouting pile and is at a same level as an external revetment where the ends of the underwater channel foundation pit along the water banks is seated.

10. The waterproof curtain at ends of an underwater channel foundation pit along water banks according to claim 1, wherein the second high-pressure jet grouting pile, the third high-pressure jet grouting pile and the first high-pressure jet grouting pile therebelow are arranged along both lengthwise and widthwise directions of the ends of the underwater channel foundation pit along the water banks so as to form a structure that is enclosed on three sides.