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(54) INCREMENTAL LAUNCHING PROCESS FOR A SUBMERGED CABLE-STAYED FLOATING TUNNEL

HERSTELLUNGSVERFAHREN FÜR EINEN IN EINEM GEWÄSSER SCHWIMMENDEN UND MITTELS SEILEN ABGESpanNTEN TUNNEL

PROCESSUS DE LANCEMENT PROGRESSIF D'UN TUNNEL FLOTTANT À HAUBANS IMMERGÉ

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GB-A- 2 016 065 US-A- 5 899 635

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a submerged floating tunnel, and more particularly to an incremental launching process for a submerged cable-stayed floating tunnel.

BACKGROUND OF THE INVENTION

[0002] "Submerged Floating Tunnel" is abbreviated as "SFT" in English. It is also called "Archimedes Bridge", or "PDA" bridge for short in Italy. Generally, it is composed of a tubular body floating in the water at a certain depth (the tubular body has a large space enough to meet the requirements of road and railway traffic), a support system (anchor cables anchored on the seabed, piers or buoyancy tanks on the water), and structures on both shores. It is a novel structure for means of transportation to cross both shores separated by deep water, is suitable for all means of transportation that need to travel through the water, can be passed by trains, cars, small motor vehicles and pedestrians, and can also be made into service channels through which various pipes and cables pass. The difference between the submerged floating tunnel and the traditional submerged tunnel or tunneling tunnel is: the floating tunnel structure is surrounded by water, is neither on the ground nor crossing the ground, but mainly depends on the gravity of its own structure, the buoyancy of the structure and the anchoring force of the support system to retain at a fixed position. The floating tunnel is sealed all around. This structure has all the characteristics of an ordinary tunnel. From the perspective of use, it should be regarded as a "tunnel" rather than a "bridge".

[0003] The floating tunnel can traverse different waters, such as rivers, fjords, straits and lakes etc., and provides a possible and acceptable form of fixed spanning structures for the places that are considered uncrossable due to deep water or long distance between both shores. The floating tunnel is built at a certain depth underwater. Compared with the open water channel and ferry transportation, bad weathers such as wind, waves, fog, rain and snow etc. will not affect all-weather operation of the floating tunnel. Under the premise of ensuring the same navigable capacity, the floating tunnel has a smoother slope and a shorter total length than a bridge. The construction and use of the floating tunnel will not affect the environment and natural landscape. When a certain span and water depth is exceeded, the unit cost of the floating tunnel will not increase significantly with the increase of span length or channel depth, while the unit costs of cable-stayed bridges and suspension bridges increase significantly with the increase of span.

[0004] Although the floating tunnel has certain advantages compared with sea-crossing channel schemes of immersed tube tunnels, deep-buried tunnels, bridges

and the like, the design and construction of the floating tunnel are still worldwide problems. So far, no floating tunnel has been built. At present, the floating tunnel is mainly researched in 7 countries (Norway, Italy, Japan, China, Switzerland, Brazil, and the United States) in the world. Many technical problems found in the research are: overall structural layout, tunnel materials, structural types of anchor systems, tunnel connection types, design of shore connecting structures, implementability of tunnel structures, construction and operation risks, etc. Whether these problems can be solved determines whether the floating tunnel can move from a feasible scheme to an actual project.

[0005] So far, in the research of floating tunnels, according to the relationship between the gravity of the floating tunnels and the buoyancy, the proposed structural types may be roughly divided into three types: pontoon type, anchored type, and pier type. The pontoon type floating tunnel is suspended on a pontoon on the water through anchor cables or chains, and the gravity of the tunnel is greater than the buoyancy, so the tunnel is greatly affected by fluctuation of the tide rise and fall in the vertical direction; the anchored type floating tunnel is anchored to an anchorage foundation under the seabed through tension legs or anchor cables, and the gravity of the tunnel is smaller than the buoyancy, so the tunnel will be displaced or wobbled under the action of hydrodynamic force; and the pier type floating tunnel is actually a tunnel bridge supported on submerged piers, and therefore, is difficult and expensive to construct. Because the tunnel floats in the water, the installation and construction of the tunnel are affected by wind, waves, currents, traveling waves etc. The three types of tunnels are very difficult in underwater localization and underwater or on-water closure, and their comfort and safety risks during underwater operation are difficult to predict.

[0006] In order to make the stress on a floating tunnel more reasonable, reduce the impact of adverse sea conditions during construction period, and be more beneficial to the control during construction period, the maintenance during operation period and the replacement of parts, a submerged cable-stayed floating tunnel structure with a cable system is disclosed. The submerged cable-stayed floating tunnel with a cable system includes a submerged floating tunnel, shore connection structures, a stay cable anchorage system, a buoyancy-weight ratio adjustment system, an anti-collision warning system, an escape system, tunnel subsidiary facilities and so on. The submerged floating tunnel is connected to the shore connection structures and connected to ground roads via land slope tunnels. Stay cables are disposed on the submerged floating tunnel and fixed on cable anchor piers located on both sides of the tunnel to form a stable stress system. Therefore, it is necessary to propose an installation and construction method, corresponding to the submerged cable-stayed floating tunnel structure with a cable system.

[0007] Document CN 1 590 658 A discloses a cable

stayed floating tunnel. Documents GB 2 016 065 A and US 5 899 635 A both disclose a fixed and anchored in place submerged tunnel. Document CN 107 700 543 A discloses a system for connecting joints in a submerged tunnel construction.

SUMMARY OF THE INVENTION

[0008] An object of the present invention is to fill the gap in the prior art and provide an incremental launching process for a submerged cable-stayed floating tunnel which is less affected by wind, waves, currents, ship waves and so on, thereby reducing the risk of offshore construction greatly, and has advantages of high construction efficiency and short construction period.

[0009] The purpose of the present invention is achieved by providing an incremental launching process for a submerged cable-stayed floating tunnel, the submerged cable-stayed floating tunnel including a tunnel body, a launching-side shore connection structure, a receiving-side shore connection structure, a cable anchorage system and a buoyancy-weight ratio adjustment system, wherein the tunnel body includes a submerged floating tunnel, a launching-side land slope tunnel and a receiving-side land slope tunnel; the launching-side shore connection structure and the receiving-side shore connection structure are respectively located on a launching-side shore and a receiving-side shore; a waterside end of the launching-side land slope tunnel and a waterside end of the receiving-side land slope tunnel are respectively connected to landside ends of the launching-side shore connection structure and the receiving-side shore connection structure;

the submerged floating tunnel is formed by connecting a plurality of pipe parts; a head of a first pipe part and a tail of a last pipe part of the submerged floating tunnel are respectively fixed in an inner cavity of the receiving-side shore connection structure and an inner cavity of the launching-side shore connection structure; each pipe part is divided into an upper tunnel layer, a middle tunnel layer and a lower tunnel layer by an upper partition and a lower partition, wherein the upper tunnel layer is a process room, the middle tunnel layer is a tunnel traffic room, and the lower tunnel layer is a water supply and drainage room;

the launching-side shore connection structure includes a scour protection section, a starting section, a retaining wall for a portal section, a portal section, a waterside wall body, a thrust section, a sealing section, a butting section, a pushing section, a horizontal transportation section and a landside wall body in turn from sea area to land area, wherein a temporary sealing gate is arranged on a front side face of the waterside wall body, with a water blocking plug disposed on the temporary sealing gate; the thrust section is a sealed box structure and has a

hoop-type thrust device; the sealing section is a sealing wall body with a wall hole, with sealing hoops respectively disposed on a front side face and a rear side face of the sealing section along a circumference of the wall hole; a water-stop strip is disposed between the wall hole and an outer surface of the corresponding pipe part; the butting section and the pushing section are both arranged in a pipe part connecting box which is capable of being opened and closed; the butting section has a stepped pipe part butting pit formed in a bottom thereof; carrying airbags are disposed on a bottom of the pushing section and a positioning section for a hydraulic pushing trolley is located at the rear of the pushing section; and the horizontal transportation section has a jacking-up beam disposed on a bottom thereof, which is driven by a jack;

the receiving-side shore connection structure includes a scour protection section, a receiving section, a retaining wall for a portal section, a portal section, a waterside wall body, a pipe part stabilizing section, a sealing section, a pipe fixing section, a drawing and anchor section and a landside wall body in turn from sea area to land area, the scour protection section, the receiving section, the retaining wall for a portal section, the portal section, the waterside wall body, the sealing section and the landside wall body of the receiving-side shore connection structure being in one-to-one correspondence with the scour protection section, the starting section, the retaining wall for a portal section, the portal section, the waterside wall body, the sealing section and the landside wall body of the launching-side shore connection structure and the corresponding parts having the same structure, wherein the waterside wall body of the receiving-side shore connection structure has a wall hole and a first sealing device is disposed along a circumference of the wall hole on a waterside face of the waterside wall body; the pipe part stabilizing section is a reinforced concrete box structure in which a hoop-type pipe part stabilizing device is disposed; the sealing section is a sealing wall with a wall hole and a second sealing device is disposed along the wall hole on a waterside face of the sealing wall; the pipe fixing section is a reinforced concrete box structure which is located behind the sealing section, with a steer sealing gate arranged on a rear end thereof; and the drawing and anchor section is located between the steer sealing gate of the pipe fixing section and the landside wall body, and a reinforced concrete abutment pier is disposed on a bottom of the drawing and anchor section, with a pile foundation disposed under the abutment pier and a traction device for traction ropes disposed on the abutment pier;

the cable anchorage system includes four cable anchorage piers, a plurality of stay cables and two temporary cable anchorage piers, wherein the four cable

anchorage piers are respectively disposed on both sides of the tunnel on the launching-side shore and on the receiving-side shore; each stay cable has a first end and a second end, the first ends of the plurality of stay cables are anchored at intervals on anchorages which are disposed on two side faces of the submerged floating tunnel, and the second ends of the plurality of stay cables are extended from the water to the ground and then anchored on the cable anchorage piers; and the two temporary cable anchorage piers are respectively disposed beside the two cable anchorage piers located on the launching-side shore; and the buoyancy-weight ratio adjustment system is arranged in the water supply and drainage room of each pipe part; the incremental launching process comprising the steps of:

- Step 1: prefabricating all the pipe parts and conducting primary outfitting of the pipe parts in a fabrication yard behind the launching-side land slope tunnel; 20
- Step 2: transporting the first pipe part from the launching-side land slope tunnel to the horizontal transportation section in the launching-side shore connection structure via a flat car, and removing the flat car after the jack drives the jacking-up beam of the horizontal transportation section to jack up the first pipe part; 25
- Step 3: conducting secondary outfitting of the first pipe part in the launching-side shore connection structure and installing a cone-shaped pushing beam and two traction ropes on a front end of the first pipe part; 30
- Step 4: inserting the carrying airbag between the first pipe part and the jacking-up beam and inflating the carrying airbag to make the first pipe part move forward to the thrust section, so that the head of the first pipe part is located behind the temporary seal gate and a tail of the first pipe part remains in the butting section for being connected to a second pipe part; and at the same time, starting the hoop-type thrust device disposed in the trust section to fix the first pipe part temporarily, then sealing the trust section; 35
- Step 5: first, transporting the second pipe part to the horizontal transportation section located in the launching-side shore connection structure; next, removing the flat car after the jack drives the jacking-up beam of the horizontal transportation section to jack up the second pipe part; then, conducting secondary outfitting of the second pipe part; then, inserting the carrying airbag between the second pipe part and the jacking-up beam, inflating the carrying airbag to make a head of the second pipe part move forward to the butting section to be connected to 40

the tail of the first pipe part, and mounting first stay cables on a front end of the second pipe part; and then setting up sealing walls at two ends of an inner cavity of the second pipe part, respectively;

Step 6: first, putting the hydraulic pushing trolley in place, closing a seal door of the pipe part connecting box, filling the pipe part connecting box with water and adjusting a buoyancy-weight ratio for the first time; then loosening the hoop-type thrust device so that the first pipe part and the second pipe part are in a floating state; and then starting the hydraulic pushing trolley to push the first pipe part and the second pipe part to move forward;

Step 7: at the beginning of pushing the first pipe part and the second pipe part, pushing the water blocking plug disposed on the temporary sealing gate open via the pushing beam which is disposed on the front end of the first pipe part, and pulling the two traction ropes into the receiving-side shore connection structure by a floating crane and connecting the two traction ropes to the traction device in the drawing and anchor section;

Step 8: during pushing the first pipe part and the second pipe part, tightening the two traction ropes by the traction device located in the drawing and anchor section, and keeping pulling the first pipe part and the second pipe part in front and pushing the first pipe part and the second pipe part behind until a tail of the second pipe part remains in the butting section of the launching-side shore connection structure;

Step 9: pulling the first stay cables onto the two temporary cable anchorage piers located on the launching-side shore;

Step 10: first, starting the hoop-type thrust device disposed in the trust section to fix the second pipe part temporarily and starting the sealing hoops disposed on the sealing wall body; then draining the pipe part connecting box, and then opening the seal door of the pipe part connecting box and removing the hydraulic pushing trolley;

Step 11: connecting and pushing a plurality of the pipe parts in turn, which are from a third pipe part to the one that follows a mid-span pipe part, by repeating Step 5, Step 6 and Steps 8-10, wherein every time one pipe part is pushed, the stay cables, which are located on front ends of the pipe parts that have been pushed out of the launching-side shore connection structure, are pulled onto the two temporary cable anchorage piers on the launching-side shore in turn; and when the pipe part that follows the mid-span pipe part is pushed, the first stay cables are pulled from the two temporary cable anchorage piers

to the two cable anchorage piers located on the receiving-side shore by the floating crane;

Step 12: connecting and pushing the other pipe parts in turn, which are from a pipe part following the one that is behind the mid-span pipe part to the last pipe part, by repeating Step 5, Step 6 and Steps 8-10, wherein every time one pipe part is pushed, the stay cables, from second stay cables located on the third pipe part to stay cables located on the mid-span pipe part, are pulled onto the two cable anchorage piers located on the receiving-side shore in turn, and the stay cables, from stay cables located on the pipe part following the mid-span pipe part to stay cables located on the last pipe part, are pulled onto the two cable anchorage piers located on the launching-side shore in turn, until the last pipe part is pushed in place, thereby the tail of the last pipe part remains in the butting section and the head of the first pipe part extends into the pipe fixing section of the receiving-side shore connection structure; and starting the sealing devices disposed in the receiving-side shore connection structure to seal the head of the first pipe part, and at the same time, starting the hoop-type thrust device disposed in the launching-side shore connection structure to fix the tail of the last pipe part temporarily;

Step 13: draining the pipe part connecting box and removing the hydraulic pushing trolley, then consolidating the tail of the last pipe part in the launching-side shore connection structure; and at the same time, draining the pipe fixing section of the receiving-side shore connection structure, removing the pushing beam, the two traction ropes, and the abutment pier and the traction device located in the drawing and anchor section, and consolidating the head of the first pipe part in the receiving-side shore connection structure;

Step 14: performing subsequent facility construction in the submerged cable-stayed floating tunnel, which includes removal of the sealing walls in each pipe part, road construction of the submerged floating tunnel, installation and internal decoration of wind facilities, water facilities and electric facilities in the submerged floating tunnel; and at the same time, adjusting the buoyancy-weight ratio for the second time;

Step 15: adjusting the buoyancy-weight ratio for the third time by injecting water into the water supply and drainage rooms of the pipe parts part by part; and

Step 16: adjusting cable force of the stay cables one by one, and then sealing-off and covering the stay cables.

[0010] In Step 5 of a preferred embodiment of the in-

cremental launching process for a submerged cable-stayed floating tunnel according to the invention, the second pipe part and the first pipe part are connected under a dry construction condition, and the second pipe part and the first pipe part are connected by pipe joints, joint fasteners, joint filling materials and joint sealing materials.

[0011] In Step 7 and Step 8 of a preferred embodiment of the incremental launching process for a submerged cable-stayed floating tunnel according to the invention, the first pipe part and the second pipe part are pushed under a wet construction condition.

[0012] In Step 13 of a preferred embodiment of the incremental launching process for a submerged cable-stayed floating tunnel according to the invention, an outer surface of the head of the first pipe part and an inner surface of the pipe fixing section of the receiving-side shore connection structure are consolidated by pouring concrete, and an outer surface of the tail of the last pipe part and an inner surface of the pipe part connecting box of the launching-side shore connection structure is consolidated by pouring concrete.

[0013] In a preferred embodiment of the incremental launching process for a submerged cable-stayed floating tunnel according to the invention, the buoyancy-weight ratio is adjusted for the first time, the second time and the third time by injecting water into or pumping water out of the water supply and drainage room of each pipe part.

[0014] The incremental launching process for a submerged cable-stayed floating tunnel of the present invention has the following features:

1. The pipe parts of the present invention are installed under a dry construction condition in the launching-side shore connection structure, which is less affected by wind, waves, currents, ship waves and so on, thereby reducing the risk of offshore construction greatly;
2. Without a floating connection or an underwater pendulum connection, the present invention reduces the difficulty of construction and avoids the risk of collisions between the pipe parts, thereby ensuring the structural safety;
3. Besides pulling the traction ropes, the present invention has a low frequency of using construction ships, so the construction has little influence on surface ship traffic and the seal hoops are greatly reduced.
4. The present invention adopts the factory-like connection to connect the pipe parts in the shore connection structure, so the connection precision is greatly improved, the water stop effects are greatly enhanced, and the overall quality of the tunnel is more controllable.
5. The present invention is basically carried out under a dry construction condition in land area, so there is no need to select an installation window period

and the present invention has high construction efficiency and short construction period.

6. The present invention basically doesn't need large-scale ship machines, which greatly shortens the construction period and reduce the costs.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

FIG. 1 is a plan view of a submerged cable-stayed floating tunnel adapted for an incremental launching process of the present invention;

FIG. 2 is a longitudinal cut view of the submerged cable-stayed floating tunnel adapted for the incremental launching process of the present invention;

FIG. 3 is a transverse cut view of the submerged cable-stayed floating tunnel adapted for the incremental launching process of the present invention;

FIG. 4 is a longitudinal sectional view of a launching-side shore connection structure of the submerged cable-stayed floating tunnel adapted for the incremental launching process of the present invention;

FIG. 5 is a longitudinal sectional view of a receiving-side shore connection structure of the submerged cable-stayed floating tunnel adapted for the incremental launching process of the present invention;

FIG. 6 is an arrangement view of an incremental launching arrangement used in the incremental launching process for a submerged cable-stayed floating tunnel of the present invention;

FIG. 7 is a state view illustrating the incremental launching process for a submerged cable-stayed floating tunnel of the present invention at Step 5;

FIG. 8 is a state view illustrating the incremental launching process for a submerged cable-stayed floating tunnel of the present invention at Step 6;

FIG. 9 is a state view illustrating the incremental launching process for a submerged cable-stayed floating tunnel of the present invention at Step 8; and

FIG. 10 is a plan view illustrating the incremental launching process for a submerged cable-stayed floating tunnel of the present invention at Step 8.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] The present invention will be further described below in combination with the drawings.

[0017] Please refer to Figs. 1-10, a floating tunnel, adapted for an incremental launching process for a submerged cable-stayed floating tunnel of the present invention, includes a tunnel body, a launching-side shore connection structure 2, a receiving-side shore connection structure 2', a cable anchorage system and a buoyancy-weight ratio adjustment system. The tunnel body includes a submerged floating tunnel 1, a launching-side land slope tunnel 6 and a receiving-side land slope tunnel 6'.

The launching-side shore connection structure 2 and the receiving-side shore connection structure 2' are located on a launching-side shore 5 and a receiving-side shore 5', respectively. A waterside end of the launching-side land slope tunnel 6 and a waterside end of the receiving-side land slope tunnel 6' are connected to landside ends of the launching-side shore connection structure 2 and the receiving-side shore connection structure 2', respectively. The submerged floating tunnel 1 is formed by connecting a plurality of pipe parts 10, and a head of a first pipe part and a tail of a last pipe part of the submerged floating tunnel 1 are fixed in an inner cavity of the receiving-side shore connection structure 2 and an inner cavity of the launching-side shore connection structure 2', respectively. Each pipe part 10 is divided into an upper tunnel layer, a middle tunnel layer and a lower tunnel layer by an upper partition and a lower partition, and the upper tunnel layer is a process room, the middle tunnel layer is a tunnel traffic room, and the lower tunnel layer is a water supply and drainage room.

[0018] From sea area to land area, the launching-side shore connection structure 2, in turn, includes a scour protection section 21, a starting section 22, a retaining wall for a portal section 2A, a portal section 23, a waterside wall body 2B, a thrust section 24, a sealing section 25, a butting section 26, a pushing section 27, a horizontal transportation section 28 and a landside wall body 2C. A temporary sealing gate 231 and corresponding sealing devices are arranged on a front side face of the waterside wall body 2B, with a water blocking plug disposed on the temporary sealing gate 231. The thrust section 24 is a sealed box structure in which a hoop-type thrust device 240 is set. The sealing section 25 is a sealing wall body with a wall hole, sealing hoops are respectively disposed on a front side face and a rear side face of the sealing wall body along a circumference of the wall hole, and water-stop strips are disposed between the wall hole and an outer surface of the corresponding pipe part 10. The butting section 26 and the pushing section 27 are both arranged in a pipe part connecting box 20 which is capable of being opened and sealed. The butting section 26 has a stepped pipe part butting pit 260 formed in a bottom thereof. Carrying airbags are placed on a bottom of the pushing section 27, and a positioning section for a hydraulic pushing trolley 270 is located at the rear of the pushing section 27. The horizontal transportation section 28 has a jacking-up beam disposed on a bottom thereof, which may be driven by a jack. When the pushing operation of all the pipe parts is completed, the tail of the last pipe part 10 remains in the butting section 26, and concrete is poured between an outer surface of the tail of the last pipe part 10 and an inner surface of the pipe part connecting box 20 so that the last pipe part 10 and the launching-side shore connection structure 2 are consolidated together.

[0019] From sea area to land area, the receiving-side shore connection structure 2', in turn, includes a scour protection section 21, a receiving section 22', a retaining

wall for a portal section 2A, a portal section 23, a waterside wall body 2B, a pipe part stabilizing section 24', a sealing section 25, a pipe fixing section 26', a drawing and anchor section 27' and a landside wall body 2C. The scour protection section 21, the receiving section 22', the retaining wall for a portal section 2A, the portal section 23, the waterside wall body 2B, the sealing section 25 and the landside wall body 2C of the receiving-side shore connection structure 2' are in one-to-one correspondence with the scour protection section 21, the starting section 22, the retaining wall for a portal section 2A, the portal section 23, the waterside wall body 2B, the sealing section 25 and the landside wall body 2C of the launching-side shore connection structure 2, that is, the corresponding parts have the same structure and function.

[0020] The waterside wall body 2B of the receiving-side shore connection structure 2' has a wall hole formed through the waterside wall body 2B. Sealing devices 232 are disposed along the wall hole on a waterside face of the receiving-side shore connection structure 2', and the sealing devices 232 adopt sealing hoops on which rubber water-stop strips are disposed. The pipe part stabilizing section 24' is a sealing box structure, with a manhole formed in a top thereof and an embedded cover disposed in the manhole. Further, hoop-type pipe part stabilizing devices are disposed in the pipe part stabilizing section 24' for stable control of postures of the pipe parts 10 after the pipe parts 10 are pushed into the pipe part stabilizing section 24'. The sealing section 25 is a sealing wall with a wall hole, and on a waterside face of the sealing wall, there also are sealing devices 232 disposed along the wall hole. Water-stop strips are placed between the wall hole and an outer surface of the corresponding pipe part 10. The pipe fixing section 26' is located behind the sealing section 25 and has the same structure as the pipe part stabilizing section 24', that is, it is also a reinforced concrete box structure. A steer sealing gate 26A is arranged on a rear end of the pipe fixing section 26' to form a sealed cabin with the pipe fixing section 26', thereby preventing seawater from flowing backwards. After the first pipe part 10 is pushed into the pipe fixing section 26', the sealing device 232 disposed on the waterside wall body 2B and the sealing device 232 disposed on the sealing section 25 are opened and the pipe fixing section 26' is drained to achieve a dry construction condition, and then the concrete, which is located on an outer surface of the head of the first pipe part 10 located in the pipe fixing section 26', is poured, so that the first pipe part 10 and the receiving-side shore connection structure 2' are consolidated together. The drawing and anchor section 27' is located between the steer sealing gate 26A of the pipe fixing section 26' and the landside wall body 2C. A reinforced concrete abutment pier is disposed on a bottom of the drawing and anchor section 27', and a pile foundation is disposed under the abutment pier and a traction device 27A with high power for traction ropes 12 is disposed on the abutment pier. After the pipe parts are pushed into place and fixed, the abutment pier and

the traction device 27A are removed, and then the head of the first pipe part and the receiving-side land slope tunnel 6' are connected to each other by cast-in-place reinforced concrete.

[0021] The cable anchorage system includes four cable anchorage piers 4, a plurality of stay cables 3 and two temporary cable anchorage piers 4A. Two of the cable anchorage piers 4 are disposed on both sides of the tunnel on the launching-side shore 5 respectively, and the other two cable anchorage piers 4 are disposed on both sides of the tunnel on the receiving-side shore 5' respectively. Each stay cable 3 has a first end and a second end. The first ends of the plurality of stay cables 3 are anchored at intervals on anchorages 30 which are disposed on two side faces of the submerged floating tunnel 1, and the second ends of the plurality of stay cables 3 are extended from the water to the ground and then anchored on the cable anchorage piers 4. The two temporary cable anchorage piers 4A are respectively disposed beside the two cable anchorage piers 4 which are located on the launching-side shore 5. The two temporary cable anchorage piers 4A are adopted for temporary anchorage of the stay cables 3 located on the front half-span pipe parts during the pushing operation. When the pipe parts are pushed more than halfway, the temporarily anchored stay cables are pulled to the receiving-side shore 5' by a floating crane to be connected to traction ropes which are prearranged in underwater steering piers, and then tightened by the cable anchorage piers 4 located on the receiving-side shore 5' and fixed on the cable anchorage piers 4.

[0022] The buoyancy-weight ratio adjustment system is arranged in the water supply and drainage room of each pipe part 10.

[0023] The incremental launching process for a submerged cable-stayed floating tunnel of the present invention includes the steps as follows.

Step 1: prefabricating all the pipe parts and conducting primary outfitting of the pipe parts in a fabrication yard 100 behind the launching-side land slope tunnel 6;

Step 2: transporting the first pipe part from the launching-side land slope tunnel 6 to the horizontal transportation section 28 in the launching-side shore connection structure 2 via a flat car, and removing the flat car after the jack drives the jacking-up beam of the horizontal transportation section 28 to jack up the first pipe part;

Step 3: conducting secondary outfitting of the first pipe part in the launching-side shore connection structure 2, and installing a cone-shaped pushing beam 11 and two traction ropes 12 on a front end of the first pipe part;

Step 4: inserting the carrying airbag between the first pipe part and the jacking-up beam and inflating the carrying airbag to make the first pipe part move forward to the thrust section 24, so that the head of the

first pipe part is located behind the temporary seal gate 231 and a tail of the first pipe part remains in the butting section 26 for being connected to a second pipe part, and at the same time, starting the hoop-type thrust device 240 disposed in the trust section 24 to fix the first pipe part temporarily;

Step 5: first, transporting the second pipe part to the horizontal transportation section 28 located in the launching-side shore connection structure 2; next, removing the flat car after the jack drives the jacking-up beam of the horizontal transportation section 28 to jack up the second pipe part; then conducting secondary outfitting of the second pipe part; then, inserting the carrying airbag between the second pipe part and the jacking-up beam, inflating the carrying airbag to make a head of the second pipe part move forward to the butting section 26 to be connected to the tail of the first pipe part, and mounting first stay cables 3 on a front end of the second pipe part; and then setting up sealing walls at two ends of an inner cavity of the second pipe part, respectively; wherein the head of the second pipe part and the tail of the first pipe part are connected by pipe joints, joint fasteners, joint filling materials and joint sealing materials, and the joint fasteners include internal fasteners and external fasteners, the internal fasteners are a vertical anchoring type and each includes a high-strength stainless steel bolt which is mainly used for bearing shear force, and a nut and a gasket matching the bolt, and the external fasteners include a plurality of anchor sockets which are arranged on the inner surface of each pipe part and close to an opening of each pipe part, and steel strands or prestressed steel bars which are connected between the anchor sockets of every two connected pipe parts 10 by the anchorages, and the external fasteners are mainly used for being tensioned when the pipe parts 10 are connected to each other and involved in bearing a horizontal tensile force during tunnel operation period;

Step 6: first, putting the hydraulic pushing trolley 270 in place, closing a seal door of the pipe part connecting box 20, filling the pipe part connecting box 20 with water and adjusting a buoyancy-weight ratio for the first time; then loosening the hoop-type thrust device 240 so that the two pipe parts are in a floating state; and then starting the hydraulic pushing trolley 270 to push the two pipe parts to move forward;

Step 7: at the beginning of pushing the two pipe parts, pushing the water blocking plug disposed on the temporary sealing gate 231 open via the pushing beam 11 which is disposed on the front end of the first pipe part, so as to balance an internal water pressure and an external water pressure, thereby it is easy to push the temporary sealing gate 231 open; and then pulling the two traction ropes 12 into the receiving-side shore connection structure 2' by the floating crane and connecting the two traction ropes 12 to the trac-

tion device 27A in the drawing and anchor section 27';

Step 8: during the pushing operation, tightening the two traction ropes 12 by the traction device 27A located in the drawing and anchor section 27', and keeping pulling the first pipe part and the second pipe part in front and pushing the first pipe part and the second pipe part behind until a tail of the second pipe part remains in the butting section 26 of the launching-side shore connection structure 2;

Step 9: pulling the first stay cables 3 onto the two temporary cable anchorage piers 4A located on the launching-side shore 5;

Step 10: first, starting the hoop-type thrust device 240 disposed in the trust section 24 to fix the second pipe part temporarily and starting the sealing hoops disposed on the sealing wall 25; then draining the pipe part connecting box 20, and then opening the seal door of the pipe part connecting box 20 and removing the hydraulic pushing trolley 270;

Step 11 connecting and pushing a plurality of the pipe parts in turn, which are from a third pipe part to the one that follows a mid-span pipe part, by repeating Step 5, Step 6 and Steps 8-10, wherein every time one pipe part is pushed, the stay cables 3, which are located on the front ends of the pipe parts that have been pushed out of the launching-side shore connection structure 2, are pulled onto the two temporary cable anchorage piers 4A on the launching-side shore 5 in turn; and when the pipe part that follows the mid-span pipe part is pushed, the first stay cables 3 are pulled from the two temporary cable anchorage piers 4A to the cable anchorage piers 4 placed on the receiving-side shore 5' by the floating crane;

Step 12: connecting and pushing the other pipe parts in turn, which are from a pipe part following the one that is behind the mid-span pipe part to the last pipe part, by repeating Step 5, Step 6 and Steps 8-10, wherein every time one pipe part is pushed, the stay cables 3, from second stay cables 3 located on the third pipe part to stay cables 3 located on the mid-span pipe part, are pulled onto the two cable anchorage piers 4 located on the receiving-side shore 5' in turn, and the stay cables, from stay cables 3 located on the pipe part following the mid-span pipe part to stay cables 3 located on the last pipe part, are pulled onto the two cable anchorage piers 4 located on the launching-side shore 5 in turn, until the last pipe part is pushed in place, thereby the tail of the last pipe part remains in the butting section 26 and the head of the first pipe part extends into the pipe fixing section 26' of the receiving-side shore connection structure 2'; and starting the sealing devices 232 disposed in the receiving-side shore connection structure 2' to seal the head of the first pipe part, and at the same time, starting the hoop-type thrust device 240 disposed in the launching-side shore connection struc-

ture 2 to fix the tail of the last pipe part temporarily; Step 13: draining the pipe part connecting box 20 and removing the hydraulic pushing trolley 270, then pouring concrete between the outer surface of the tail of the last pipe part and the inner surface of the pipe part connecting box 20 of the launching-side shore connection structure 2 so that the tail of the last pipe part is consolidated in the launching-side shore connection structure 2; and at the same time, draining the pipe fixing section 26' of the receiving-side shore connection structure 2' dry, removing the pushing beam 11, the two traction ropes 12, and the abutment pier and the traction device 27A located in the drawing and anchor section 27'; and then pouring concrete between the outer surface of the head of the first pipe part and the inner surface of the pipe fixing section 26' of the receiving-side shore connection structure 2' so that the head of the first pipe part is consolidated in the receiving-side shore connection structure 2';

Step 14: performing the subsequent facility construction in the submerged cable-stayed floating tunnel, which includes removal of the sealing walls in each pipe part 10, road construction of the submerged floating tunnel 1, installation and internal decoration of wind facilities, water facilities and electric facilities in the submerged floating tunnel 1; and at the same time, adjusting the buoyancy-weight ratio for the second time;

Step 15: adjusting the buoyancy-weight ratio for the third time by injecting water into or pumping water out of the water supply and drainage rooms of the pipe parts 10 part by part; and

Step 16: adjusting the cable force of the stay cables 3 one by one, and then sealing-off and covering the stay cables.

[0024] The overall process of the incremental launching process for a submerged cable-stayed floating tunnel includes: prefabricating all the pipe parts of the tunnel in land, transporting the pipe parts in the land slope tunnel, connecting the pipe parts in the shore connection structures, and wet-pushing the pipe parts and pulling and locating the traction ropes simultaneously after dry-wet transformation.

[0025] Considering the design buoyancy-weight ratio of the pipe parts is equal to 1 during the pushing operation, in the present invention, the buoyancy-weight ratio is adjusted to the design buoyancy-weight ratio by water ballasting of the pipe parts. When the pipe parts are pushed and installed, buoyancy is used to support the weight of the pipe parts to keep them basically at the design depth in the water. According to Archimede's floating law, when gravity is equal to buoyancy, in theory, objects in water may stay anywhere in the water of the same density; moreover, seawater density generally increases with depth, that is, buoyancy increases with depth, so the sealed pipe parts which are pushed into

water won't float or sink, but they may shake up and down. The shaking amplitude of the pipe parts is related to currents and waves, and the larger the current force is, the greater the shaking amplitude is. Therefore, it is necessary to use the stay cables to restrict the pipe parts and properly decrease the buoyancy-weight ratio simultaneously, so that the pipe parts are in a downward trend.

[0026] Under the action of horizontal forces generated by currents, waves and so on, the pipe parts which are pushed into the water will rotate and displace, so the pipe parts need to be limited. It is different from an incremental launching process for bridges, there is no support and restriction of temporary piers when a pipe part is pushed in the water, so the pipe part is easy to deviate from its direction and a large horizontal bending moment is produced at the portion of the pipe part which enters the water. Thus, the present invention takes three measures, the first one is to set a starting section outside the launching-side shore connection structure for stating limit; the second one is to set the traction ropes on the headmost end of the pipe parts, anchor the traction ropes in the receiving-side shore connection structure in advance, and pull the pipe parts in front and push the pipe parts behind during the pushing operation; and the third one is to use the stay cables to carry horizontal loads and vertical loads to maintain the pipe parts in a desired direction.

[0027] A dry construction method is used to connect the pipe parts in the present invention, which is executed in the launching-side shore connection structure. After the pipe parts are connected, the secondary outfitting is conducted. So the butting section is arranged in the launching-side shore connection structure, that is, the tail of the pushed pipe part is exposed under a dry construction condition in the launching-side shore connection structure 2 for easy connection. For achieving the dry construction condition, it is necessary to form a seal between the launching-side shore connection structure and the pushed pipe part, so the sealing section is arranged in the launching-side shore connection structure, and only the tail of the pipe part is located under the dry condition. Due to the transformation between the dry condition and the wet condition, the pushed pipe part will be pushed in a reverse direction under deep water pressure outside the launching-side shore connection structure. So the pushed pipe part must be fixed temporarily and the thrust operation starts. The present invention takes three thrust measures, the first one is to set the thrust section in the launching-side shore connection structure, which adopts the hoop-type thrust device to provide the friction force between its hoop and the pipe part; the second one is to pull the pipe part on the opposite shore with the traction ropes disposed on the front end of the pipe part; and the third one is to set the cone-shaped beam on the front end of the pipe part to reduce water pressure.

[0028] In the present, a wet pushing method is used to push the pipe parts, that is, the pipe parts are pushed when the entire pipe parts suspend in water. In the

launching-side shore connection structure, the butting section and the pushing section are arranged in the pipe part connecting box and the hydraulic pushing trolley driven by underwater gears is installed for pushing the pipe parts. Before the pushing operation, the pipe part connecting box is sealed and filled with water so as to completely immerse the hydraulic pushing trolley and the connected pipe parts, and then the thrust device is loosened so that the pipe parts are in a floating state. Since the balance of water pressure in front of the pipe parts and behind the pipe parts is maintained, the pushing operation is only affected by water resistance caused by the moving speed of the pipe parts, that is, it is easy to push the pipe parts. During the pushing operation, the hydraulic pushing trolley pushes the pipe parts along its track to the butting section, and at the same time, the traction ropes located on the front end of the pipe parts are tightened, which means pulling the pipe parts in front and pushing the pipe parts behind. When the pushing trip for one pipe part ends, the thrust device is started for temporary fixation and the sealing hoops of the sealing section are started for seal. Then the pipe part connecting box is drained, and the pipe part connecting box corresponding to the butting section is opened, so that the tail of the pipe part is exposed under the dry construction condition, and it starts to execute the loop of connecting, sealing, injecting and pushing for a next pipe part.

[0029] In the present invention, the temporary sealing gate is arranged outside the waterside wall body of the launching-side shore connection structure and the water blocking plug is disposed on the temporary sealing gate which is fastened under deep water pressure outside the wall body. During the pushing operation, the blocking plug is opened to balance the internal water pressure and the external water pressure, and therefore, it is easy to push the temporary sealing gate open. There is no temporary sealing gate outside the waterside wall body of the receiving-side shore connection structure, but the steer sealing gate is disposed behind the drawing and anchor section. After the pipe part enters the steer sealing gate, the pipe part is fixed temporarily and the concrete is poured around the pipe part. When the two ends of the tunnel and the corresponding pipe parts are consolidated together, the steel sealing gates located on the two ends of the tunnel are opened.

[0030] During the implementation of the incremental launching process for a submerged cable-stayed floating tunnel of the present invention, the buoyancy-weight ratio of the pipe parts is adjusted in three stages. The buoyancy-weight ratio is adjusted for the first time after the pipe parts are connected and before the pushing operation begins, and the first adjustment is mainly to ensure that the submerged floating tunnel is capable of suspending in water during the pushing operation. The buoyancy-weight ratio is adjusted for the second time during performing the subsequent construction of the road and subsidiary facilities in the submerged floating tunnel, and the second adjustment is mainly to ensure that the stress

systems of the submerged floating tunnel meet the design requirements since the construction of the subsidiary facilities in the submerged floating tunnel causes an increase of the weight of the tunnel. The buoyancy-weight ratio is adjusted for the third time after the subsequent construction of the facilities in the submerged floating tunnel, and it mainly takes into account the load distribution of the submerged floating tunnel during its operation period.

[0031] Before the pipe part is pushed and installed, the buoyancy-weight ratio is adjusted to be slightly less than 1 by injecting water into the pipe part, that is, the adjustment of the buoyancy-weight ratio is mainly achieved by storing water in the water supply and drainage room of the pipe part. The density of water at the water depth where the pipe part is located is obtained by sampling and measurement. The density of the reinforced concrete of the pipe part is obtained by weighing a trial-produced reinforced concrete block model. The volume of the reinforced concrete of the pipe part is determined by actual measurement.

[0032] The subsequent road construction in the submerged floating tunnel is carried out in sections, and at the same time, according to the added weight, water is pumped out of the corresponding pipe part and the weight of the corresponding pipe part is reduced in order to ensure that the buoyancy-weight ratio meets the design requirements.

[0033] After the subsequent construction of the facilities in the submerged floating tunnel is completed, water is injected in sections in order to adjust the buoyancy-weight ratio to the design value, and at the same time, the cable force of the stay cables is measured in sections and the stay cables are tightened until the cable tension reaches to the design value.

[0034] In the process of pushing the pipe parts toward the receiving-side shore connection structure, it is needed to increase the length of the stay cables properly and maintain the corresponding tension to hold the positions and postures of the pipe parts. Therefore, according to the structural design requirements, a certain length of each stay cable is reserved and placed in an anchor well, and the corresponding length of stay cable may be released as required. The stay cables are tightened or released by the special traction device and stress sensors are installed on the stay cables to monitor the tension stress of the stay cables in real time.

Claims

1. An incremental launching process for a submerged cable-stayed floating tunnel, the submerged cable-stayed floating tunnel including a tunnel body, a launching-side shore connection structure (2), a receiving-side shore connection structure (2'), a cable anchorage system and a buoyancy-weight ratio adjustment system, wherein the tunnel body includes

a submerged floating tunnel (1), a launching-side land slope tunnel (6) and a receiving-side land slope tunnel (6'); the launching-side shore connection structure (2) and the receiving-side shore connection structure (2') are respectively located on a launching-side shore (5) and a receiving-side shore (5'); a waterside end of the launching-side land slope tunnel (6) and a waterside end of the receiving-side land slope tunnel (6') are respectively connected to land-side ends of the launching-side shore connection structure (2) and the receiving-side shore connection structure (2');

the submerged floating tunnel (1) is formed by connecting a plurality of pipe parts (10); a head of a first pipe part (10) and a tail of a last pipe part (10) of the submerged floating tunnel (1) are respectively fixed in an inner cavity of the receiving-side shore connection structure (2') and an inner cavity of the launching-side shore connection structure (2); each pipe part (10) is divided into an upper tunnel layer, a middle tunnel layer and a lower tunnel layer by an upper partition and a lower partition, wherein the upper tunnel layer is a process room, the middle tunnel layer is a tunnel traffic room, and the lower tunnel layer is a water supply and drainage room; the launching-side shore connection structure (2) includes a scour protection section (21), a starting section (22), a retaining wall (2A) for a portal section (23), a portal section (23), a waterside wall body (2B), a thrust section (24), a sealing section (25), a butting section (26), a pushing section (27), a horizontal transportation section (28) and a landside wall body (2C) in turn from sea area to land area, wherein a temporary sealing gate (231) is arranged on a front side face of the waterside wall body (2B), with a water blocking plug disposed on the temporary sealing gate (231); the thrust section (24) is a sealed box structure and has a hoop-type thrust device (240); the sealing section (25) is a sealing wall body with a wall hole, with sealing hoops respectively disposed on a front side face and a rear side face of the sealing section (25) along a circumference of the wall hole; a water-stop strip is disposed between the wall hole and an outer surface of the corresponding pipe part (10); the butting section (26) and the pushing section (27) are both arranged in a pipe part connecting box (20) which is capable of being opened and closed; the butting section (26) has a stepped pipe part butting pit (260) formed in a bottom thereof; carrying airbags are disposed on a bottom of the pushing section (27) and a positioning section for a hydraulic pushing trolley (270) is located at the rear of the pushing section (27); and the horizontal transportation

section (28) has a jacking-up beam disposed on a bottom thereof, which is driven by a jack; the receiving-side shore connection structure (2') includes a scour protection section (21), a receiving section (22'), a retaining wall (2A) for a portal section (23), a portal section (23), a waterside wall body (2B), a pipe part stabilizing section (24'), a sealing section (25), a pipe fixing section (26'), a drawing and anchor section (27') and a landside wall body (2C) in turn from sea area to land area, the scour protection section (21), the receiving section (22'), the retaining wall (2A) for a portal section (23), the portal section (23), the waterside wall body (2B), the sealing section (25) and the landside wall body (2C) of the receiving-side shore connection structure (2') being in one-to-one correspondence with the scour protection section (21), the starting section (22), the retaining wall (2A) for a portal section (23), the portal section (23), the waterside wall body (2B), the sealing section (25) and the landside wall body (2C) of the launching-side shore connection structure (2) and the corresponding parts having the same structure, wherein the waterside wall body (2B) of the receiving-side shore connection structure (2') has a wall hole and a first sealing device (232) is disposed along a circumference of the wall hole on a waterside face of the waterside wall body (2B); the pipe part stabilizing section (24') is a reinforced concrete box structure in which a hoop-type pipe part stabilizing device is disposed; the sealing section (25) is a sealing wall with a wall hole and a second sealing device (232) is disposed along the wall hole on a waterside face of the sealing wall; the pipe fixing section (26') is a reinforced concrete box structure which is located behind the sealing section (25), with a steer sealing gate (26A) arranged on a rear end thereof; and the drawing and anchor section (27') is located between the steer sealing gate (26A) of the pipe fixing section (26') and the landside wall body (2C), and a reinforced concrete abutment pier is disposed on a bottom of the drawing and anchor section (27'), with a pile foundation disposed under the abutment pier and a traction device (27A) for traction ropes (12) disposed on the abutment pier; the cable anchorage system includes four cable anchorage piers (4), a plurality of stay cables (3) and two temporary cable anchorage piers (4A), wherein the four cable anchorage piers (4) are respectively disposed on both sides of the tunnel on the launching-side shore (5) and on the receiving-side shore (5'); each stay cable (3) has a first end and a second end, the first ends of the plurality of stay cables (3) are anchored at intervals on anchorages (30) which are dis-

posed on two side faces of the submerged floating tunnel (1), and the second ends of the plurality of stay cables (3) are extended from the water to the ground and then anchored on the cable anchorage piers (4); and the two temporary cable anchorage piers (4A) are respectively disposed beside the two cable anchorage piers (4) located on the launching-side shore (5); and the buoyancy-weight ratio adjustment system is arranged in the water supply and drainage room of each pipe part (10); the incremental launching process comprising the steps of:

Step 1: prefabricating all the pipe parts (10) and conducting primary outfitting of the pipe parts (10) in a fabrication yard (100) behind the launching-side land slope tunnel (6);
 Step 2: transporting the first pipe part (10) from the launching-side land slope tunnel (6) to the horizontal transportation section (28) in the launching-side shore connection structure (2) via a flat car, and removing the flat car after the jack drives the jacking-up beam of the horizontal transportation section (28) to jack up the first pipe part (10);
 Step 3: conducting secondary outfitting of the first pipe part (10) in the launching-side shore connection structure (2) and installing a cone-shaped pushing beam and two traction ropes (12) on a front end of the first pipe part (10);
 Step 4: inserting the carrying airbag between the first pipe part (10) and the jacking-up beam and inflating the carrying airbag to make the first pipe part (10) move forward to the thrust section (24), so that the head of the first pipe (10) part is located behind the temporary seal gate and a tail of the first pipe part (10) remains in the butting section (26) for being connected to a second pipe part (10); and at the same time, starting the hoop-type thrust device (240) disposed in the thrust section (24) to fix the first pipe part (10) temporarily, then sealing the thrust section (24);
 Step 5: first, transporting the second pipe part (10) to the horizontal transportation section (28) located in the launching-side shore connection structure (2); next, removing the flat car after the jack drives the jacking-up beam of the horizontal transportation section (28) to jack up the second pipe part (10); then, conducting secondary outfitting of the second pipe part (10); then, inserting the carrying airbag between the second pipe part (10) and the jacking-up beam, inflating the carrying airbag to make a head

of the second pipe part (10) move forward to the butting section (26) to be connected to the tail of the first pipe part (10), and mounting first stay cables (3) on a front end of the second pipe part (10); and then setting up sealing walls at two ends of an inner cavity of the second pipe part (10), respectively;

Step 6: first, putting the hydraulic pushing trolley (270) in place, closing a seal door of the pipe part connecting box (20), filling the pipe part connecting box (20) with water and adjusting a buoyancy-weight ratio for the first time; then loosening the hoop-type thrust device (240) so that the first pipe part (10) and the second pipe part (10) are in a floating state; and then starting the hydraulic pushing trolley (270) to push the first pipe part (10) and the second pipe part (10) to move forward;

Step 7: at the beginning of pushing the first pipe part (10) and the second pipe part (10), pushing the water blocking plug disposed on the temporary sealing gate (231) open via the pushing beam which is disposed on the front end of the first pipe part (10), and pulling the two traction ropes (12) into the receiving-side shore connection structure (2') by a floating crane and connecting the two traction ropes (12) to the traction device (27A) in the drawing and anchor section (27');

Step 8: during pushing the first pipe part (10) and the second pipe part (10), tightening the two traction ropes (12) by the traction device (27A) located in the drawing and anchor section (27'), and keeping pulling the first pipe part (10) and the second pipe part (10) in front and pushing the first pipe part (10) and the second pipe part (10) behind until a tail of the second pipe part (10) remains in the butting section (26) of the launching-side shore connection structure (2);

Step 9: pulling the first stay cables (3) onto the two temporary cable anchorage piers (4A) located on the launching-side shore (5);

Step 10: first, starting the hoop-type thrust device (240) disposed in the thrust section (24) to fix the second pipe part (10) temporarily and starting the sealing hoops disposed on the sealing wall body; then draining the pipe part connecting box (20), and then opening the seal door of the pipe part connecting box (20) and removing the hydraulic pushing trolley (270);

Step 11: connecting and pushing a plurality

of the pipe parts (10) in turn, which are from a third pipe part (10) to the one that follows a mid-span pipe part (10), by repeating Step 5, Step 6 and Steps 8-10, wherein every time one pipe part (10) is pushed, the stay cables (3), which are located on front ends of the pipe parts (10) that have been pushed out of the launching-side shore connection structure (2), are pulled onto the two temporary cable anchorage piers (4A) on the launching-side shore (5) in turn; and when the pipe part (10) that follows the mid-span pipe part (10) is pushed, the first stay cables (3) are pulled from the two temporary cable anchorage piers (4A) to the two cable anchorage piers (4) located on the receiving-side shore (5') by the floating crane;

Step 12: connecting and pushing the other pipe parts (10) in turn, which are from a pipe part (10) following the one that is behind the mid-span pipe part (10) to the last pipe part (10), by repeating Step 5, Step 6 and Steps 8-10, wherein every time one pipe part (10) is pushed, the stay cables (3), from second stay cables (3) located on the third pipe part (10) to stay cables (3) located on the mid-span pipe part (10), are pulled onto the two cable anchorage piers (4) located on the receiving-side shore (5') in turn, and the stay cables (3), from stay cables (3) located on the pipe part (10) following the mid-span pipe part (10) to stay cables (3) located on the last pipe part (10), are pulled onto the two cable anchorage piers (4) located on the launching-side shore (5) in turn, until the last pipe part (10) is pushed in place, thereby the tail of the last pipe part (10) remains in the butting section (26) and the head of the first pipe part (10) extends into the pipe fixing section (26') of the receiving-side shore connection structure (2'); and starting the sealing devices (232) disposed in the receiving-side shore connection structure (2') to seal the head of the first pipe part (10), and at the same time, starting the hoop-type thrust device (240) disposed in the launching-side shore connection structure (2) to fix the tail of the last pipe part (10) temporarily;

Step 13: draining the pipe part connecting box (20) and removing the hydraulic pushing trolley (270), then consolidating the tail of the last pipe part (10) in the launching-side shore connection structure (2); and at the same time, draining the pipe fixing section (26') of the receiving-side shore connection structure (2'), removing the pushing beam, the two traction ropes (12), and the

abutment pier and the traction device (27A) located in the drawing and anchor section (27'), and consolidating the head of the first pipe part (10) in the receiving-side shore connection structure (2');

Step 14: performing subsequent facility construction in the submerged cable-stayed floating tunnel, which includes removal of the sealing walls in each pipe part (10),

road construction of the submerged floating tunnel (1), installation and internal decoration of wind facilities, water facilities and electric facilities in the submerged floating tunnel (1); and at the same time, adjusting the buoyancy-weight ratio for the second time;

Step 15: adjusting the buoyancy-weight ratio for the third time by injecting water into the water supply and drainage rooms of the pipe parts (10) part by part; and

Step 16: adjusting cable force of the stay cables (3) one by one, and then sealing-off and covering the stay cables (3).

2. The incremental launching process for a submerged cable-stayed floating tunnel as claimed in claim 1, **characterized in that** in Step 5, the second pipe part (10) and the first pipe part (10) are connected under a dry construction condition, and the second pipe part (10) and the first pipe part (10) are connected by pipe joints, joint fasteners, joint filling materials and joint sealing materials.
3. The incremental launching process for a submerged cable-stayed floating tunnel as claimed in claim 1, **characterized in that** in Step 7 and Step 8, the first pipe part (10) and the second pipe part (10) are pushed under a wet construction condition.
4. The incremental launching process for a submerged cable-stayed floating tunnel as claimed in claim 1, **characterized in that** in Step 13, an outer surface of the head of the first pipe part (10) and an inner surface of the pipe fixing section (26') of the receiving-side shore connection structure (2') are consolidated by pouring concrete, and an outer surface of the tail of the last pipe part (10) and an inner surface of the pipe part connecting box (20) of the launching-side shore connection structure (2) is consolidated by pouring concrete.
5. The incremental launching process for a submerged cable-stayed floating tunnel as claimed in claim 1, **characterized in that** the buoyancy-weight ratio is adjusted for the first time, the second time and the third time by injecting water into or pumping water out of the water supply and drainage room of each

pipe part (10).

Patentansprüche

1. Herstellungsverfahren für einen getauchten, seilgespannten, schwimmenden Tunnel, wobei der getauchte, seilgespannte, schwimmende Tunnel einen Tunnelkörper, eine sendeseitige Uferverbindungsstruktur (2), eine empfangsseitige Uferverbindungsstruktur (2'), ein Seilverankerungssystem und ein System zum Einstellen des Auftriebs-Gewichts-Verhältnisses umfasst, wobei der Tunnelkörper einen getauchten schwimmenden Tunnel (1), einen sendeseitigen Landböschungstunnel (6) und einen empfangsseitigen Landböschungstunnel (6') umfasst; wobei die sendeseitige Uferverbindungsstruktur (2) und die empfangsseitige Uferverbindungsstruktur (2') an einem sendeseitigen Ufer (5) beziehungsweise einem empfangsseitigen Ufer (5') angeordnet sind; wobei ein wasserseitiges Ende des sendeseitigen Landböschungstunnels (6) und ein wasserseitiges Ende des empfangsseitigen Landböschungstunnels (6') jeweils mit den landseitigen Enden der sendeseitigen Uferverbindungsstruktur (2) und der empfangsseitigen Uferverbindungsstruktur (2') verbunden sind;

wobei der getauchte schwimmende Tunnel (1) durch Verbinden einer Vielzahl von Rohrteilen (10) gebildet wird; wobei ein Anfang eines ersten Rohrteils (10) und ein Ende eines letzten Rohrteils (10) des getauchten schwimmenden Tunnels (1) jeweils in einem inneren Hohlraum der empfangsseitigen Uferverbindungsstruktur (2') und einem inneren Hohlraum der sendeseitigen Uferverbindungsstruktur (2) fixiert sind; wobei jeder Rohrteil (10) durch eine obere Trennwand und eine untere Trennwand in eine obere Tunnelebene, eine mittlere Tunnelebene und eine untere Tunnelebene unterteilt ist, wobei die obere Tunnelebene ein Prozessraum ist, wobei die mittlere Tunnelebene ein Tunnelverkehrsraum ist, und wobei die untere Tunnelebene ein Wasserversorgungs- und Entwässerungsraum ist; wobei die sendeseitige Uferverbindungsstruktur (2) einen Kolkschutzabschnitt (21), einen Startabschnitt (22), eine Stützwand (2A) für einen Portalabschnitt (23), einen Portalabschnitt (23), einen wasserseitigen Wandkörper (2B), einen Druckabschnitt (24), einen Dichtungsabschnitt (25), einen Stoßabschnitt (26), einen Schubabschnitt (27), einen horizontalen Transportabschnitt (28) und einen landseitigen Wandkörper (2C) nacheinander vom Wasserbereich zum Landbereich umfasst, wobei ein temporäres Dichtungstor (231) an einer vorderen Seitenfläche des wasserseitigen Wandkörpers (2B) an-

geordnet ist, wobei ein Wassersperrstopfen an dem temporären Dichtungstor (231) angeordnet ist; wobei der Druckabschnitt (24) eine abgedichtete Kastenstruktur ist und eine ringförmige Druckvorrichtung (240) aufweist; wobei der Stoßabschnitt (25) ein Dichtungswandkörper mit einem Wandloch ist, wobei Dichtungsringe jeweils auf einer vorderen Seitenfläche und einer hinteren Seitenfläche des Dichtungsabschnitts (25) entlang eines Umfangs des Wandlochs angeordnet sind; wobei ein Wassersperrstreifen zwischen dem Wandloch und einer Außenfläche des entsprechenden Rohrteils (10) angeordnet ist; wobei der Stoßabschnitt (26) und der Schubabschnitt (27) beide in einem Rohrteil-Verbindungskasten (20) angeordnet sind, der geöffnet und geschlossen werden kann; wobei der Stoßabschnitt (26) in seinem Boden eine abgestufte Rohrteil-Stoßgrube (260) aufweist; wobei an einem Boden des Schubabschnitts (27) tragende Luftsäcke angeordnet sind und an der Rückseite des Schubabschnitts (27) ein Positionierabschnitt für einen hydraulischen Schubwagen (270) angeordnet ist; und wobei der horizontale Transportabschnitt (28) einen an seinem Boden angeordneten Hebebalken aufweist, der von einem Heber angetrieben wird;

wobei die empfangsseitige Uferverbindungsstruktur (2') einen Kolkschutzabschnitt (21), einen Empfangsabschnitt (22'), eine Stützwand (2A) für einen Portalabschnitt (23), einen Portalabschnitt (23), einen wasserseitigen Wandkörper (2B), einen Rohrteil-Stabilisierungsabschnitt (24'), einen Dichtungsabschnitt (25), einen Rohrbefestigungsabschnitt (26'), einen Zug- und Ankerabschnitt (27') und einen landseitigen Wandkörper (2C) wiederum vom Wasserbereich zum Landbereich umfasst, wobei der Kolkschutzabschnitt (21), der Empfangsabschnitt (22'), die Stützwand (2A) für einen Portalabschnitt (23), der Portalabschnitt (23), der wasserseitige Wandkörper (2B), der Dichtungsabschnitt (25) und der landseitige Wandkörper (2C) der empfangsseitigen Uferverbindungsstruktur (2') in Eins-zu-Eins-Entsprechung mit dem Kolkschutzabschnitt (21), dem Startabschnitt (22), der Stützwand (2A) für einen Portalabschnitt (23), dem Portalabschnitt (23), dem wasserseitigen Wandkörper (2B), dem Dichtungsabschnitt (25) und dem landseitigen Wandkörper (2C) der sendeseitigen Uferverbindungsstruktur (2) stehen und die entsprechenden Teile die gleiche Struktur aufweisen, wobei der wasserseitige Wandkörper (2B) der empfangsseitigen Uferverbindungsstruktur (2') ein Wandloch aufweist und eine erste Dichtungs- vorrichtung (232) entlang eines Umfangs des

Wandlochs auf einer wasserseitigen Fläche des wasserseitigen Wandkörpers (2B) angeordnet ist; wobei der Rohrteil-Stabilisierungsabschnitt (24') eine Stahlbeton-Kastenstruktur ist, in der eine ringförmige Rohrteil-Stabilisierungsvorrichtung angeordnet ist; 5
wobei der Dichtungsabschnitt (25) eine Dichtungswand mit einem Wandloch ist und eine zweite Dichtungsvorrichtung (232) entlang des Wandlochs an einer wasserseitigen Fläche der Dichtungswand angeordnet ist; wobei der Rohrbefestigungsabschnitt (26') eine Stahlbeton-Kastenstruktur ist, die hinter dem Dichtungsabschnitt (25) angeordnet ist, wobei eine Steuer-Dichtungstür (26 A) an einem hinteren Ende davon angeordnet ist; 10
und wobei der Zug- und Ankerabschnitt (27') zwischen der Steuer-Dichtungstür (26 A) des Rohrbefestigungsabschnitts (26') und dem landseitigen Wandkörper (2C) angeordnet ist und ein Widerlagerpfeiler aus Stahlbeton an einem Boden des Zug- und Ankerabschnitts (27') angeordnet ist, wobei ein Pfahlfundament unter dem Widerlagerpfeiler und eine Zugvorrichtung (27 A) für Zugseile (12) an dem Widerlagerpfeiler angeordnet ist; 20
wobei das Seilverankerungssystem vier Seilverankerungspfeiler (4), eine Vielzahl von Schrägseilen (3) und zwei temporäre Seilverankerungspfeiler (4A) umfasst, wobei die vier Seilverankerungspfeiler (4) jeweils auf beiden Seiten des Tunnels am sendeseitigen Ufer (5) und am empfangsseitigen Ufer (5') angeordnet sind; wobei jedes Schrägseil (3) ein erstes Ende und ein zweites Ende aufweist, wobei die ersten Enden der mehreren Schrägseile (3) an Verankerungen (30) beabstandet verankert sind, die an zwei Seitenflächen des getauchten schwimmenden Tunnels (1) angeordnet sind, und wobei die zweiten Enden der Vielzahl von Schrägseilen (3) aus dem Wasser auf den Boden geführt und dann an den Seilverankerungspfeilern (4) verankert werden; und wobei die beiden temporären Seilverankerungspfeiler (4A) jeweils neben den beiden am sendeseitigen Ufer (5) befindlichen Seilverankerungspfeilern (4) angeordnet sind; und wobei das System zum Einstellen des Auftriebs-Gewichts-Verhältnisses in dem Wasserversorgungs- und Entwässerungsraum jedes Rohrteils (10) angeordnet ist; 25
wobei das Herstellungsverfahren die folgenden Schritte umfasst:

Schritt 1: Vorfertigen aller Rohrteile (10) und Durchführen einer primären Montage der Rohrteile (10) in einem Fertigungsgelände (100) hinter dem sendeseitigen Landböschungstunnel (6); 30

Schritt 2: Transportieren des ersten Rohrteils (10) von dem sendeseitigen Landböschungstunnel (6) zu dem horizontalen Transportabschnitt (28) in der sendeseitigen Uferverbindungsstruktur (2) mittels eines Flachwagens und Entfernen des Flachwagens, nachdem der Heber den Hebebalken des horizontalen Transportabschnitts (28) antreibt, um das erste Rohrteil (10) anzuheben;

Schritt 3: Durchführen einer sekundären Montage des ersten Rohrteils (10) in der sendeseitigen Uferverbindungsstruktur (2) und Anbringen eines kegelförmigen Schubalkens und zweier Zugseile (12) an einem vorderen Ende des ersten Rohrteils (10);

Schritt 4: Einsetzen des tragenden Luftsacks zwischen dem ersten Rohrteil (10) und dem Hebebalken und Aufblasen des tragenden Luftsacks, um den ersten Rohrteil (10) vorwärts zu dem Stoßabschnitt (24) zu bewegen, sodass der Anfang des ersten Rohrteils (10) hinter dem temporären Dichtungstor angeordnet ist und ein Ende des ersten Rohrteils (10) in dem Stoßabschnitt (26) verbleibt, um mit einem zweiten Rohrteil (10) verbunden zu werden; und gleichzeitig Starten der ringförmigen Druckvorrichtung (240), die in dem Druckabschnitt (24) angeordnet ist, um das erste Rohrteil (10) vorübergehend zu fixieren, und dann Abdichten des Druckabschnitts (24);

Schritt 5: zunächst Transportieren des zweiten Rohrteils (10) zu dem horizontalen Transportabschnitt (28), der in der sendeseitigen Uferverbindungsstruktur (2) angeordnet ist; anschließend Entfernen des Flachwagens, nachdem der Heber den Hebebalken des horizontalen Transportabschnitts (28) antreibt, um das zweite Rohrteil (10) anzuheben; dann Durchführen der sekundären Montage des zweiten Rohrteils (10); Einsetzen des Luftsacks zwischen dem zweiten Rohrteil (10) und dem Hebebalken, Aufblasen des Luftsacks, damit sich der Anfang des zweiten Rohrteils (10) zu dem Stoßabschnitt (26) bewegt, um mit dem Ende des ersten Rohrteils (10) verbunden zu werden, und Anbringen der ersten Schrägseile (3) an einem vorderen Ende des zweiten Rohrteils (10); und anschließend Aufstellen von Dichtungswänden an zwei Enden eines inneren Hohlraums des zweiten Rohrteils (10);

Schritt 6: zuerst In-Position-Bringen des hydraulischen Schubwagens (270), Schließen einer Dichtungstür des Rohrteil-Verbindungskastens (20), Füllen des Rohrteil-

Verbindungskastens (20) mit Wasser und zum ersten Mal Einstellen eines Auftriebs-Gewichts-Verhältnisses; dann Lösen der ringförmigen Druckvorrichtung (240), so-
 dass sich das erste Rohrteil (10) und das
 zweite Rohrteil (10) in einem schwimmen-
 den Zustand befinden; und dann Starten
 des hydraulischen Schubwagens (270), um
 das erste Rohrteil (10) und das zweite Rohr-
 teil (10) vorwärts zu schieben;
 Schritt 7: zu Beginn des Schiebens des ers-
 ten Rohrteils (10) und des zweiten Rohrteils
 (10) Aufschieben des an der temporären
 Dichtungstür (231) angeordneten Wasser-
 sperrstopfens über den Schiebebalken, der
 an dem vorderen Ende des ersten Rohrteils
 (10) angeordnet ist, und Einziehen der bei-
 den Zugseile (12) in die empfangsseitige
 Uferverbindungsstruktur (2') durch einen
 Schwimmkran und Verbinden der beiden
 Zugseile (12) mit der Zugvorrichtung (27 A)
 in dem Zug- und Ankerabschnitt (27');
 Schritt 8: während des Schiebens des ers-
 ten Rohrteils (10) und des zweiten Rohrteils
 (10) Straffen der beiden Zugseile (12) durch
 die Zugvorrichtung (27 A), die in dem Zug-
 und Ankerabschnitt (27') angeordnet ist,
 und Weiterziehen des ersten Rohrteils (10)
 und des zweiten Rohrteils (10) nach vorne
 und Schieben des ersten Rohrteils (10) und
 des zweiten Rohrteils (10) nach hinten, bis
 ein Ende des zweiten Rohrteils (10) in dem
 Stoßabschnitt (26) der sendeseitigen Ufer-
 verbindungsstruktur (2) bleibt;
 Schritt 9: Ziehen der ersten Schrägseile (3)
 auf die beiden temporären Seilverankerungspfeiler (4A), die sich an dem sendeseitigen Ufer (5) befinden;
 Schritt 10: zunächst Starten der ringförmigen Druckvorrichtung (240), die in dem Druckabschnitt (24) angeordnet ist, um das zweite Rohrteil (10) vorübergehend zu fixieren, und der Dichtungsringe, die auf dem Dichtungswand-Körper angeordnet sind; dann Entleeren des Rohrteil-Verbindungskastens (20) und anschließendes Öffnen der Dichtungstür des Rohrteil-Verbindungskastens (20) und Entfernen des hydraulischen Schubwagens (270);
 Schritt 11: Verbinden und Schieben einer Vielzahl von Rohrteilen (10) der Reihe nach, die von einem dritten Rohrteil (10) bis zu demjenigen reichen, der einem Rohrteil (10) in der Mitte der Spannweite folgt, indem Schritt 5, Schritt 6 und die Schritte 8-10 wiederholt werden, wobei jedes Mal ein Rohrteil (10) geschoben wird, wobei die Schrägseile (3), die an den vorderen Enden der

Rohrteile (10) angeordnet sind, die aus der sendeseitigen Uferverbindungsstruktur (2) herausgeschoben wurden, nacheinander auf die beiden temporären Seilverankerungspfeiler (4A) an dem sendeseitigen Ufer (5) gezogen werden; und wobei, wenn das Rohrteil (10), das auf das Rohrteil (10) in der Mitte der Spannweite folgt, geschoben wird, die ersten Schrägseile (3) durch den Schwimmkran von den beiden temporären Seilverankerungspfeilern (4A) zu den beiden Seilverankerungspfeilern (4) an dem empfangsseitigen Ufer (5') gezogen werden;
 Schritt 12: Verbinden und Schieben der anderen Rohrteile (10) der Reihe nach, und zwar von einem Rohrteil (10), das demjenigen folgt, das sich hinter dem Rohrteil (10) in der Mitte der Spannweite befindet, bis zu dem letzten Rohrteil (10), indem Schritt 5, Schritt 6 und die Schritte 8-10 wiederholt werden, wobei jedes Mal ein Rohrteil (10) geschoben wird, wobei die Schrägseile (3) von den zweiten Schrägseilen (3), die an dem dritten Rohrteil (10) angeordnet sind, bis zu den Schrägseilen (3), die an dem mittleren Rohrteil (10) angeordnet sind, nacheinander auf die beiden Seilverankerungspfeiler (4) an dem empfangsseitigen Ufer (5') gezogen werden, und wobei die Schrägseile (3) von den Schrägseilen (3) auf dem Rohrteil (10) nach dem mittleren Rohrteil (10) bis zu den Schrägseilen (3) auf dem letzten Rohrteil (10) nacheinander auf die beiden Seilverankerungspfeiler (4) auf dem sendeseitigen Ufer (5) gezogen werden, bis das letzte Rohrteil (10) eingeschoben ist, wobei das Ende des letzten Rohrteils (10) in dem Stoßabschnitt (26) verbleibt und der Anfang des ersten Rohrteils (10) in den Rohrbefestigungsabschnitt (26') der empfangsseitigen Uferverbindungsstruktur (2') hineinragt; und Starten der in der empfangsseitigen Uferverbindungsstruktur (2') angeordneten Druckvorrichtungen (232), um den Anfang des ersten Rohrteils (10) abzudichten, und gleichzeitiges Starten der in der empfangsseitigen Uferverbindungsstruktur (2) angeordneten ringförmigen Druckvorrichtung (240), um das Ende des letzten Rohrteils (10) vorübergehend zu fixieren;
 Schritt 13: Entleeren des Rohrteil-Verbindungskastens (20) und Entfernen des hydraulischen Schubwagens (270), dann Zusammenfügen des Endstücks des letzten Rohrteils (10) in der sendeseitigen Uferverbindungsstruktur (2); und gleichzeitig Ent-

- leeren des Rohrbefestigungsabschnitts (26') der empfangsseitigen Uferverbindungsstruktur (2'), Entfernen des Schubalkens, der beiden Zugseile (12) und des Widerlagers und der Zugvorrichtung (27 A), die in dem Zug- und Ankerabschnitt (27') angeordnet sind, und Zusammenfügen des Anfangs des ersten Rohrteils (10) in der empfangsseitigen Uferverbindungsstruktur (2');
 Schritt 14: Durchführen des anschließenden Aufbaus von Einrichtungen in dem getauchten seilgespannten schwimmenden Tunnel, der das Entfernen der Dichtungswände in jedem Rohrteil (10), den Straßenbau des getauchten schwimmenden Tunnels (1), die Installation und die Innenausstattung von Luft-, Wasser- und elektrischen Einrichtungen in dem getauchten schwimmenden Tunnel (1) umfasst, und gleichzeitig Einstellen des Auftriebs-Gewichts-Verhältnisses zum zweiten Mal;
 Schritt 15: Einstellen des Auftriebs-Gewichts-Verhältnisses zum dritten Mal durch teilweises Einspritzen von Wasser in die Wasserversorgungs- und Entwässerungsräume der Rohrteile (10); und Schritt 16: Einstellen der Seilkraft der Schrägseile (3) nacheinander und anschließendes Abdichten und Abdecken der Schrägseile (3).
2. Herstellungsverfahren für einen getauchten, seilgespannten, schwimmenden Tunnel nach Anspruch 1, **dadurch gekennzeichnet, dass** in Schritt 5 das zweite Rohrteil (10) und das erste Rohrteil (10) in einem trockenen Bauzustand verbunden werden, und das zweite Rohrteil (10) und das erste Rohrteil (10) durch Rohrverbindungen, Verbindungselemente, Verbindungsfüllmaterialien und Verbindungsdichtungsmaterialien verbunden werden.
 3. Herstellungsverfahren für einen getauchten, seilgespannten, schwimmenden Tunnel nach Anspruch 1, **dadurch gekennzeichnet, dass** in Schritt 7 und Schritt 8 das erste Rohrteil (10) und das zweite Rohrteil (10) in einem nassen Bauzustand geschoben werden.
 4. Herstellungsverfahren für einen getauchten, seilgespannten, schwimmenden Tunnel nach Anspruch 1, **dadurch gekennzeichnet, dass** in Schritt 13 eine Außenfläche des Anfangs des ersten Rohrteils (10) und eine Innenfläche des Rohrteil-Verbindungskastens (26') der empfangsseitigen Uferverbindungsstruktur (2') durch Gießen von Beton zusammengefügt werden, und dass eine Außenfläche des Endes des letzten Rohrteils (10) und eine Innenfläche des Rohrteil-Verbindungskastens (20) der sendeseiti-

gen Uferverbindungsstruktur (2) durch Gießen von Beton zusammengefügt werden.

5. Herstellungsverfahren für einen getauchten, seilgespannten, schwimmenden Tunnel nach Anspruch 1, **dadurch gekennzeichnet, dass** das Auftriebs-Gewichts-Verhältnis zum ersten Mal, zum zweiten Mal und zum dritten Mal durch Einspritzen von Wasser in den Wasserversorgungs- und Entwässerungsraum jedes Rohrteils (10) oder durch Abpumpen von Wasser aus diesem Raum eingestellt wird.

Revendications

1. Processus de lancement progressif pour un tunnel flottant à haubans immergé, le tunnel flottant à haubans immergé incluant un corps de tunnel, une structure de raccordement sur rive de côté de lancement (2), une structure de raccordement sur rive de côté de réception (2'), un système d'ancrage de câble(s) et un système de réglage du rapport flottabilité-poids, dans lequel le corps de tunnel inclut un tunnel flottant immergé (1), un tunnel dans la pente du terrain de côté de lancement (6) et un tunnel dans la pente du terrain de côté de réception (6') ; la structure de raccordement sur rive de côté de lancement (2) et la structure de raccordement sur rive de côté de réception (2') sont respectivement localisées sur une rive de côté de lancement (5) et sur une rive de côté de réception (5') ; une extrémité de côté d'eau du tunnel dans la pente du terrain de côté de lancement (6) et une extrémité de côté d'eau du tunnel dans la pente du terrain de côté de réception (6') sont respectivement raccordées à des extrémités de côté de terre de la structure de raccordement sur rive de côté de lancement (2) et de la structure de raccordement sur rive de côté de réception (2') ;

le tunnel flottant immergé (1) est formé en raccordant une pluralité de parties de tube (10) ; une tête d'une première partie de tube (10) et une queue d'une dernière partie de tube (10) du tunnel flottant immergé (1) sont respectivement fixées à l'intérieur d'une cavité interne de la structure de raccordement sur rive de côté de réception (2') et à l'intérieur d'une cavité interne de la structure de raccordement sur rive de côté de lancement (2) ; chaque partie de tube (10) est divisée selon une strate de tunnel supérieure, une strate de tunnel intermédiaire et une strate de tunnel inférieure par une séparation supérieure et par une séparation inférieure, dans lequel la strate de tunnel supérieure est un espace de processus, la strate de tunnel intermédiaire est un espace de circulation de tunnel et la strate de tunnel inférieure est un espace d'alimentation en eau et de drainage afférent ;

la structure de raccordement sur rive de côté de lancement (2) inclut une section de protection contre l'affouillement (21), une section de démarrage (22), une paroi de retenue (2A) pour une section d'entrée de tunnel (23), une section d'entrée de tunnel (23), un corps de paroi de côté d'eau (2B), une section d'élan de poussée (24), une section d'étanchéité (25), une section de venue en butée (26), une section d'effort de poussée (27), une section de transport à l'horizontale (28) et un corps de paroi de côté de terre (2C), en séquence depuis la zone de mer jusqu'à la zone de terre, dans lequel une porte à fonction de vanne d'étanchéité temporaire (231) est agencée sur une face de côté avant du corps de paroi de côté d'eau (2B), un moyen d'obturation par blocage de l'eau étant disposé sur la porte à fonction de vanne d'étanchéité temporaire (231) ; la section d'élan de poussée (24) est une structure de boîte scellée de façon étanche et elle comporte un dispositif d'élan de poussée du type arceau de scellement étanche (240) ; la section d'étanchéité (25) est un corps de paroi d'étanchéité qui comporte un trou de paroi, des arceaux de scellement étanche étant respectivement disposés sur une face de côté avant et sur une face de côté arrière de la section d'étanchéité (25) le long d'une circonférence du trou de paroi ; une bande hydrofuge à fonction d'arrêt d'eau est disposée entre le trou de paroi et une surface externe de la partie de tube correspondante (10) ; la section de venue en butée (26) et la section d'effort de poussée (27) sont toutes deux agencées à l'intérieur d'une boîte de raccordement de partie(s) de tube (20) qui peut être ouverte et fermée ; la section de venue en butée (26) comporte une dépression de venue en butée de partie(s) de tube étagée (260) qui est formée à l'intérieur de son fond ; des airbags de retenue et de soutien sont disposés sur un fond de la section d'effort de poussée (27) et une section de positionnement pour un chariot d'effort de poussée hydraulique (270) est localisée au niveau de l'arrière de la section d'effort de poussée (27) ; et la section de transport à l'horizontale (28) comporte une poutre de levage qui est disposée sur son fond, laquelle est entraînée par un vérin ;

la structure de raccordement sur rive de côté de réception (2') inclut une section de protection contre l'affouillement (21), une section de réception (22'), une paroi de retenue (2A) pour une section d'entrée de tunnel (23), une section d'entrée de tunnel (23), un corps de paroi de côté d'eau (2B), une section de stabilisation de partie de tube (24'), une section d'étanchéité (25), une section de fixation de tube (26'), une section de tirage et d'ancrage (27') et un corps

de paroi de côté de terre (2C), en séquence depuis la zone de mer jusqu'à la zone de terre, la section de protection contre l'affouillement (21), la section de réception (22'), la paroi de retenue (2A) pour une section d'entrée de tunnel (23), la section d'entrée de tunnel (23), le corps de paroi de côté d'eau (2B), la section d'étanchéité (25) et le corps de paroi de côté de terre (2C) de la structure de raccordement sur rive de côté de réception (2') étant selon une correspondance biunivoque avec la section de protection contre l'affouillement (21), la section de démarrage (22), la paroi de retenue (2A) pour une section d'entrée de tunnel (23), la section d'entrée de tunnel (23), le corps de paroi de côté d'eau (2B), la section d'étanchéité (25) et le corps de paroi de côté de terre (2C) de la structure de raccordement sur rive de côté de lancement (2) et avec les parties correspondantes qui présentent la même structure, dans lequel le corps de paroi de côté d'eau (2B) de la structure de raccordement sur rive de côté de réception (2') comporte un trou de paroi et un premier dispositif de scellement étanche (232) est disposé le long d'une circonférence du trou de paroi sur une face de côté d'eau du corps de paroi de côté d'eau (2B) ; la section de stabilisation de partie de tube (24') est une structure de boîte en béton armé à l'intérieur de laquelle un dispositif de stabilisation de partie de tube du type arceau de scellement étanche est disposé ; la section d'étanchéité (25) est une paroi d'étanchéité qui comporte un trou de paroi et un second dispositif de scellement étanche (232) est disposé le long du trou de paroi sur une face de côté d'eau de la paroi d'étanchéité ; la section de fixation de tube (26') est une structure de boîte en béton armé qui est localisée derrière la section d'étanchéité (25), une porte à fonction de vanne d'étanchéité à pilotage (26A) étant agencée sur son extrémité arrière ; et la section de tirage et d'ancrage (27') est localisée entre la porte à fonction de vanne d'étanchéité à pilotage (26A) de la section de fixation de tube (26') et le corps de paroi de côté de terre (2C), et un pilier de butée en béton armé est disposé sur un fond de la section de tirage et d'ancrage (27'), une fondation de pilier étant disposée au-dessous du pilier de butée et un dispositif de traction (27A) pour des câbles de manoeuvre par traction (12) étant disposé sur le pilier de butée ; et

le système d'ancrage de câble(s) inclut quatre piliers d'ancrage de câble(s) (4), une pluralité de câbles de haubanage (3) et deux piliers d'ancrage de câble(s) temporaires (4A), dans lequel les quatre piliers d'ancrage de câble(s) (4) sont respectivement disposés sur les deux côtés du tunnel sur la rive de côté de lancement (5) et sur

la rive de côté de réception (5') ; chaque câble de haubanage (3) comporte une première extrémité et une seconde extrémité, les premières extrémités de la pluralité de câbles de haubanage (3) sont ancrées selon des intervalles sur des ancrages (30) qui sont disposés sur deux faces latérales du tunnel flottant immergé (1), et les secondes extrémités de la pluralité de câbles de haubanage (3) sont étendues depuis l'eau jusqu'au sol puis sont ancrées sur les piliers d'ancrage de câble(s) (4) ; et les deux piliers d'ancrage de câble(s) temporaires (4A) sont respectivement disposés à côté des deux piliers d'ancrage de câble(s) (4) qui sont localisés sur la rive de côté de lancement (5), et le système de réglage de rapport flottabilité-poids est agencé à l'intérieur de l'espace d'alimentation en eau et de drainage afférent de chaque partie de tube (10) ;

le processus de lancement progressif comprenant les étapes suivantes :

Etape 1 : la préfabrication de toutes les parties de tube (10) et la mise en oeuvre d'un montage primaire par assemblage des parties de tube (10) dans une zone de fabrication (100) derrière le tunnel dans la pente du terrain de côté de lancement (6) ;

Etape 2 : le transport de la première partie de tube (10) depuis le tunnel dans la pente du terrain de côté de lancement (6) jusqu'à la section de transport à l'horizontale (28) à l'intérieur de la structure de raccordement sur rive de côté de lancement (2) via un moyen de transport à plat, et l'enlèvement du moyen de transport à plat après que le vérin a entraîné la poutre de levage de la section de transport à l'horizontale (28) pour lever la première partie de tube (10) ;

Etape 3 : la mise en oeuvre d'un montage secondaire par assemblage de la première partie de tube (10) à l'intérieur de la structure de raccordement sur rive de côté de lancement (2) et l'installation d'une poutre d'effort de poussée en forme de cône et de deux câbles de manoeuvre par traction (12) sur une extrémité avant de la première partie de tube (10) ;

Etape 4 : l'insertion de l'airbag de retenue et de soutien entre la première partie de tube (10) et la poutre de levage et le gonflage de l'airbag de retenue et de soutien pour faire en sorte que la première partie de tube (10) soit déplacée vers l'avant jusqu'à la section d'élan de poussée (24), de telle sorte que la tête de la première partie de tube (10) soit localisée derrière la porte à fonction de vanne d'étanchéité temporaire et qu'une

queue de la première partie de tube (10) reste à l'intérieur de la section de venue en butée (26) pour être raccordée à une deuxième partie de tube (10) ; et dans le même temps, le démarrage du dispositif d'élan de poussée du type arceau de scellement étanche (240) qui est disposé à l'intérieur de la section d'élan de poussée (24) pour fixer temporairement la première partie de tube (10), puis le scellement de façon étanche de la section d'élan de poussée (24) ;

Etape 5 : en premier lieu, le transport de la deuxième partie de tube (10) jusqu'à la section de transport à l'horizontale (28) qui est localisée à l'intérieur de la structure de raccordement sur rive de côté de lancement (2) ; ensuite, l'enlèvement du moyen de transport à plat après que le vérin a entraîné la poutre de levage de la section de transport à l'horizontale (28) pour lever la deuxième partie de tube (10) ; puis la mise en oeuvre du montage secondaire par assemblage de la deuxième partie de tube (10) ; puis l'insertion de l'airbag de retenue et de soutien entre la deuxième partie de tube (10) et la poutre de levage, le gonflage de l'airbag de retenue et de soutien pour faire en sorte qu'une tête de la deuxième partie de tube (10) soit déplacée vers l'avant jusqu'à la section de venue en butée (26) pour être raccordée à la queue de la première partie de tube (10), et le montage de premiers câbles de haubanage (3) sur une extrémité avant de la deuxième partie de tube (10) ; puis l'installation de parois d'étanchéité au niveau de deux extrémités d'une cavité interne de la deuxième partie de tube (10), de façon respective ;

Etape 6 : en premier lieu, la mise en place du chariot d'effort de poussée hydraulique (270), la fermeture d'une porte d'étanchéité de la boîte de raccordement de partie(s) de tube (20), le remplissage de la boîte de raccordement de partie(s) de tube (20) avec de l'eau et le réglage d'un rapport flottabilité-poids pour la première fois ; puis la désactivation du dispositif d'élan de poussée du type arceau de scellement étanche (240) de telle sorte que la première partie de tube (10) et la deuxième partie de tube (10) soient dans un état flottant ; puis le démarrage du chariot d'effort de poussée hydraulique (270) pour exercer un effort de poussée sur la première partie de tube (10) et sur la deuxième partie de tube (10) pour les déplacer vers l'avant ;

Etape 7 : au début de l'exercice de l'effort

de poussée sur la première partie de tube (10) et sur la deuxième partie de tube (10), l'exercice d'un effort de poussée sur le moyen d'obturation par blocage de l'eau qui est disposé sur la porte à fonction de vanne d'étanchéité temporaire (231) qui est ouverte via la poutre d'effort de poussée qui est disposée sur l'extrémité avant de la première partie de tube (10), et l'exercice d'une traction sur les deux câbles de manoeuvre par traction (12) à l'intérieur de la structure de raccordement sur rive de côté de réception (2') au moyen d'une grue flottante et le raccordement des deux câbles de manoeuvre par traction (12) sur le dispositif de traction (27A) à l'intérieur de la section de tirage et d'ancrage (27') ;

Etape 8 : pendant l'exercice de l'effort de poussée sur la première partie de tube (10) et sur la deuxième partie de tube (10), le serrage des deux câbles de manoeuvre par traction (12) par le dispositif de traction (27A) qui est localisé à l'intérieur de la section de tirage et d'ancrage (27'), et la poursuite de l'exercice de la traction sur la première partie de tube (10) et sur la deuxième partie de tube (10) vers l'avant et la poursuite de l'exercice de l'effort de poussée sur la première partie de tube (10) et sur la deuxième partie de tube (10) derrière jusqu'à ce qu'une queue de la deuxième partie de tube (10) reste à l'intérieur de la section de venue en butée (26) de la structure de raccordement sur rive de côté de lancement (2) ;

Etape 9 : l'exercice d'une traction sur les premiers câbles de haubanage (3) sur les deux piliers d'ancrage de câble(s) temporaires (4A) qui sont localisés sur la rive de côté de lancement (5) ;

Etape 10 : en premier lieu, le démarrage du dispositif d'élan de poussée du type arceau de scellement étanche (240) qui est disposé à l'intérieur de la section d'élan de poussée (24) pour fixer temporairement la deuxième partie de tube (10) et le démarrage des arceaux de scellement étanche qui sont disposés sur le corps de paroi d'étanchéité ; puis le drainage de la boîte de raccordement de partie(s) de tube (20), puis l'ouverture de la porte d'étanchéité de la boîte de raccordement de partie(s) de tube (20) et l'enlèvement du chariot d'effort de poussée hydraulique (270) ;

Etape 11 : le raccordement d'une pluralité des parties de tube (10) en séquence et l'exercice d'un effort de poussée sur ces mêmes parties de tube en séquence, les-

quelles vont d'une troisième partie de tube (10) à la partie de tube qui fait suite à une partie de tube de mi-longueur (10), en répétant l'Etape 5, l'Etape 6 et les Etapes 8 à 10, dans lequel, chaque fois qu'une partie de tube (10) est soumise à un effort de poussée, les câbles de haubanage (3), qui sont localisés sur des extrémités avant des parties de tube (10) qui ont été extraites hors de la structure de raccordement sur rive de côté de lancement (2) au moyen de l'exercice d'un effort de poussée, sont tirés sur les deux piliers d'ancrage de câble(s) temporaires (4A) sur la rive de côté de lancement (5) en séquence ; et lorsque la partie de tube (10) qui fait suite à la partie de tube de mi-longueur (10) est soumise à un effort de poussée, les premiers câbles de haubanage (3) sont tirés depuis les deux piliers d'ancrage de câble(s) temporaires (4A) jusqu'aux deux piliers d'ancrage de câble(s) (4) qui sont localisés sur la rive de côté de réception (5') par la grue flottante ;

Etape 12 : le raccordement des autres parties de tube (10) en séquence et l'exercice d'un effort de poussée sur ces mêmes autres parties de tube en séquence, lesquelles vont d'une partie de tube (10) qui fait suite à la partie de tube qui est derrière la partie de tube de mi-longueur (10) jusqu'à la dernière partie de tube (10), en répétant l'Etape 5, l'Etape 6 et les Etapes 8 à 10, dans lequel, chaque fois qu'une partie de tube (10) est soumise à un effort de poussée, les câbles de haubanage (3), depuis des seconds câbles de haubanage (3) qui sont localisés sur la troisième partie de tube (10) jusqu'à des câbles de haubanage (3) qui sont localisés sur la partie de tube de mi-longueur (10), sont tirés sur les deux piliers d'ancrage de câble(s) (4) qui sont localisés sur la rive de côté de réception (5') en séquence, et les câbles de haubanage (3), depuis des câbles de haubanage (3) qui sont localisés sur la partie de tube (10) qui fait suite à la partie de tube de demi-longueur (10) jusqu'à des câbles de haubanage (3) qui sont localisés sur la dernière partie de tube (10), sont tirés sur les deux piliers d'ancrage de câble(s) (4) qui sont localisés sur la rive de côté de lancement (5) en séquence, jusqu'à ce que la dernière partie de tube (10) soit soumise à un effort de poussée pour sa mise en place, de telle sorte que la queue de la dernière partie de tube (10) reste à l'intérieur de la section de venue en butée (26) et que la tête de la première partie de tube (10) soit étendue à l'intérieur

de la section de fixation de tube (26') de la structure de raccordement sur rive de côté de réception (2') ; et le démarrage des dispositifs de scellement étanche (232) qui sont disposés à l'intérieur de la structure de raccordement sur rive de côté de réception (2') pour sceller de façon étanche la tête de la première partie de tube (10) et dans le même temps, le démarrage du dispositif d'élan de poussée du type arceau de scellement étanche (240) qui est disposé à l'intérieur de la structure de raccordement sur rive de côté de lancement (2) pour fixer temporairement la queue de la dernière partie de tube (10) ;

Etape 13 : le drainage de la boîte de raccordement de partie(s) de tube (20) et l'enlèvement du chariot d'effort de poussée hydraulique (270), puis la consolidation de la queue de la dernière partie de tube (10) à l'intérieur de la structure de raccordement sur rive de côté de lancement (2) ; et dans le même temps, le drainage de la section de fixation de tube (26') de la structure de raccordement sur rive de côté de réception (2'), l'enlèvement de la poutre d'effort de poussée, des deux câbles de manoeuvre par traction (12), et du pilier de butée et du dispositif de traction (27A) qui est localisé à l'intérieur de la section de tirage et d'ancrage (27'), et la consolidation de la tête de la première partie de tube (10) à l'intérieur de la structure de raccordement sur rive de côté de réception (2') ;

Etape 14 : la réalisation d'opérations de construction d'infrastructures subséquentes à l'intérieur du tunnel flottant à haubans immergé, lesquelles opérations incluent l'enlèvement des parois d'étanchéité à l'intérieur de chaque partie de tube (10), la construction de voie(s) de circulation du tunnel flottant immergé (1), l'installation et la décoration interne d'installations pour le vent, d'installations pour l'eau et d'installations électriques à l'intérieur du tunnel flottant immergé (1) ; et dans le même temps, le réglage du rapport flottabilité-poids pour la deuxième fois ;

Etape 15 : le réglage du rapport flottabilité-poids pour la troisième fois en injectant de l'eau à l'intérieur des espaces d'alimentation en eau et de drainage afférent des parties de tube (10), partie par partie ; et

Etape 16 : le réglage de la force de câble des câbles de haubanage (3), un par un, puis le bouclage et le scellement étanche ainsi que le recouvrement des câbles de haubanage (3).

2. Processus de lancement progressif pour un tunnel flottant à haubans immergé tel que revendiqué selon la revendication 1, **caractérisé en ce que**, au niveau de l'Etape 5, la deuxième partie de tube (10) et la première partie de tube (10) sont raccordées sous une condition de construction à sec, et la deuxième partie de tube (10) et la troisième partie de tube (10) sont raccordées au moyen de raccords de tube, d'éléments de fixation de raccord, de matériaux de remplissage de raccord et de matériaux de scellement étanche de raccord.
3. Processus de lancement progressif pour un tunnel flottant à haubans immergé tel que revendiqué selon la revendication 1, **caractérisé en ce que**, au niveau de l'Etape 7 et de l'Etape 8, la première partie de tube (10) et la deuxième partie de tube (10) sont soumises à un effort de poussée sous une condition de construction humide.
4. Processus de lancement progressif pour un tunnel flottant à haubans immergé tel que revendiqué selon la revendication 1, **caractérisé en ce que**, au niveau de l'Etape 13, une surface externe de la tête de la première partie de tube (10) et une surface interne de la section de fixation de tube (26') de la structure de raccordement sur rive de côté de réception (2') sont consolidées par coulage de béton, et une surface externe de la queue de la dernière partie de tube (10) et une surface interne de la boîte de raccordement de partie(s) de tube (20) de la structure de raccordement sur rive de côté de lancement (2) sont consolidées par coulage de béton.
5. Processus de lancement progressif pour un tunnel flottant à haubans immergé tel que revendiqué selon la revendication 1, **caractérisé en ce que** le rapport flottabilité-poids est réglé pour la première fois, pour la deuxième fois et pour la troisième fois en injectant de l'eau à l'intérieur de l'espace d'alimentation en eau et de drainage afférent de chaque partie de tube (10) ou en pompant de l'eau hors de ce même espace d'alimentation en eau et de drainage afférent de chaque partie de tube (10) .

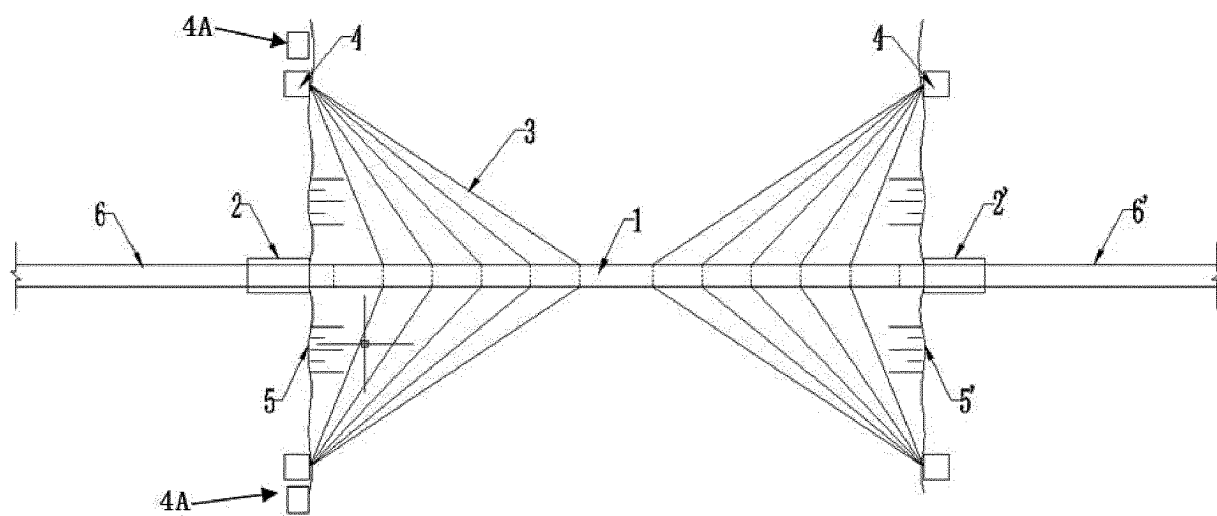


Fig.1

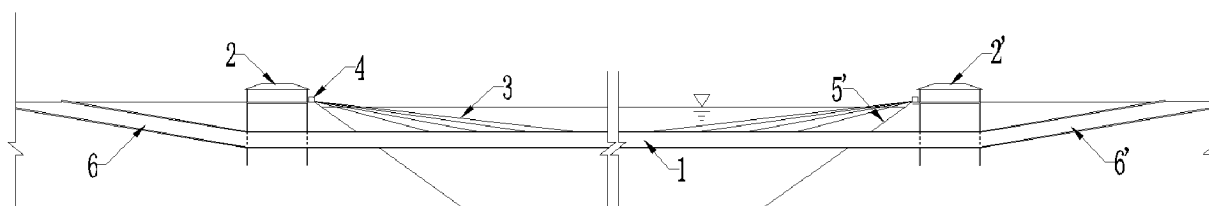


Fig.2

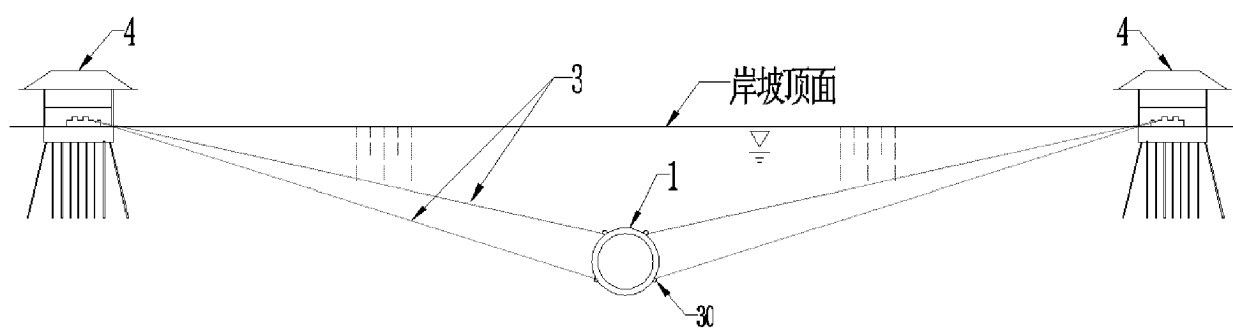


Fig.3

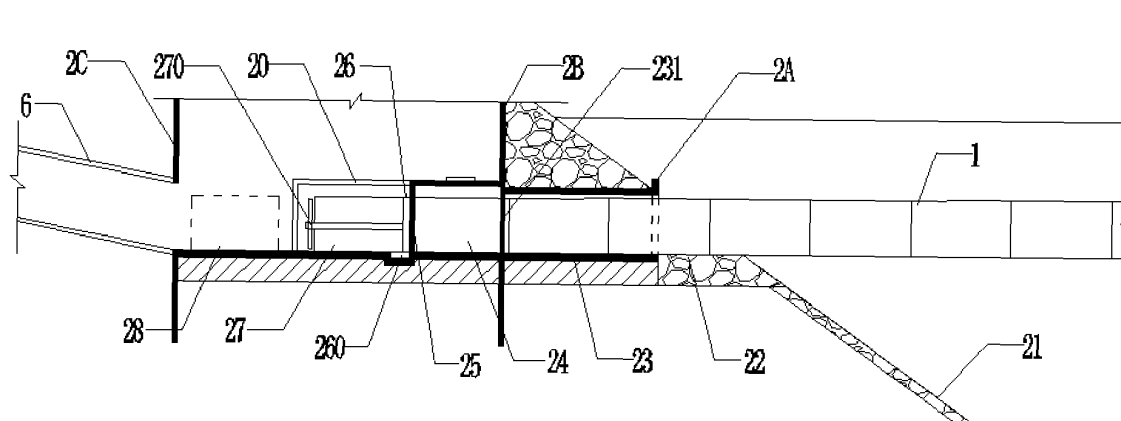


Fig.4

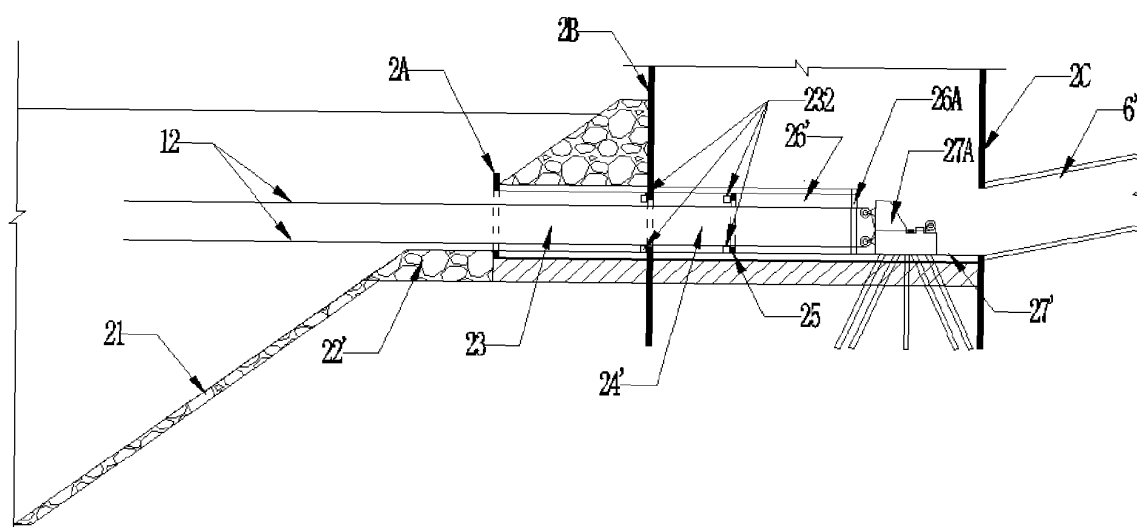


Fig.5

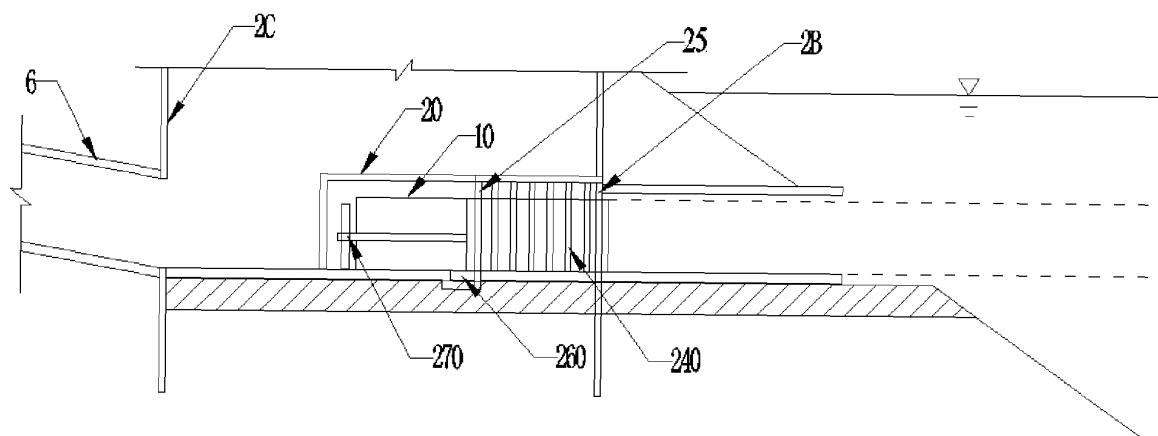


Fig.6

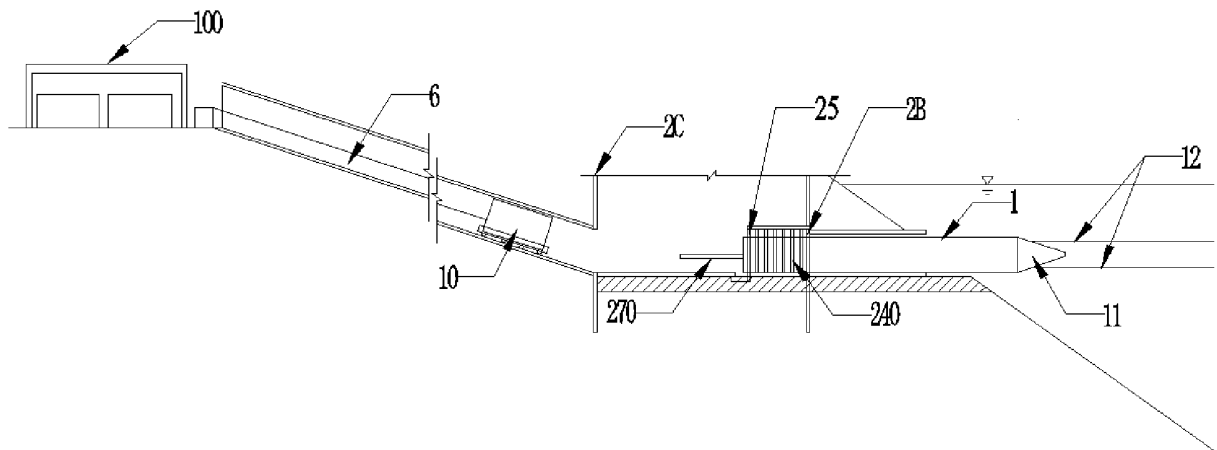


Fig.7

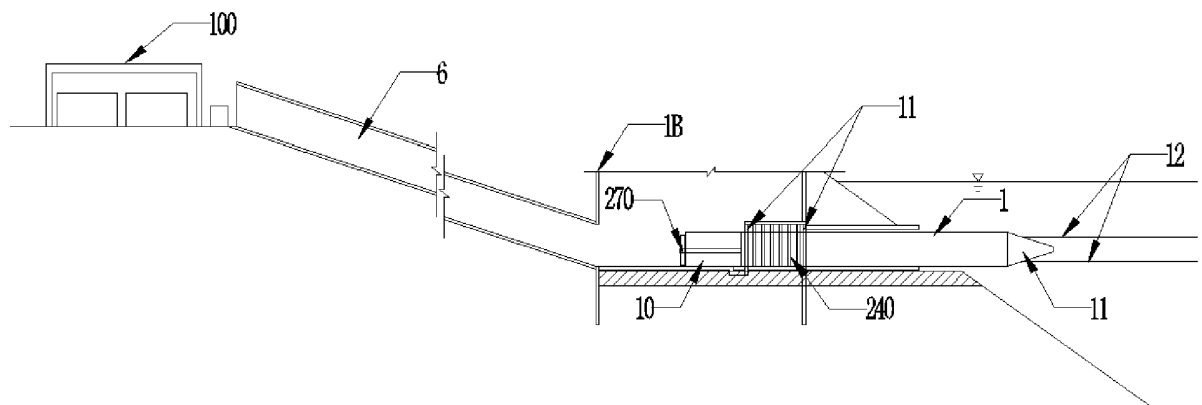


Fig.8

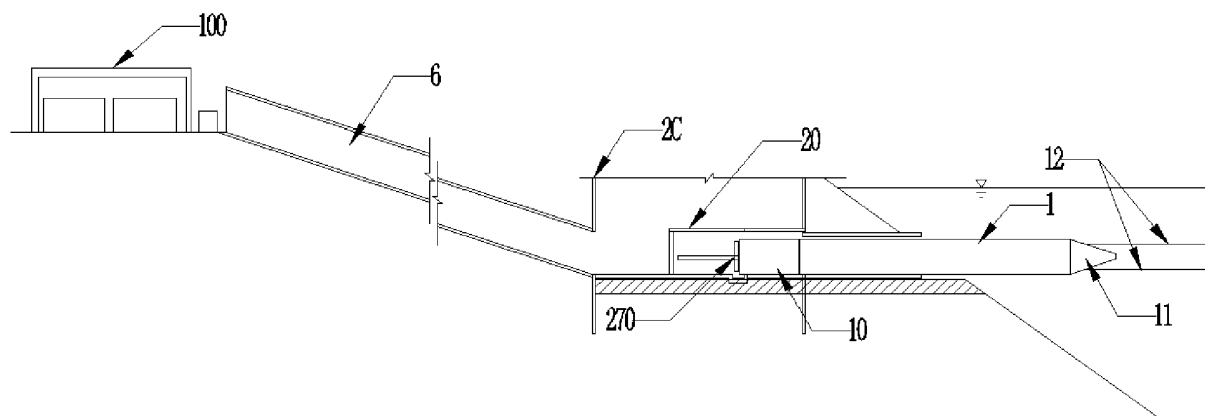


Fig.9

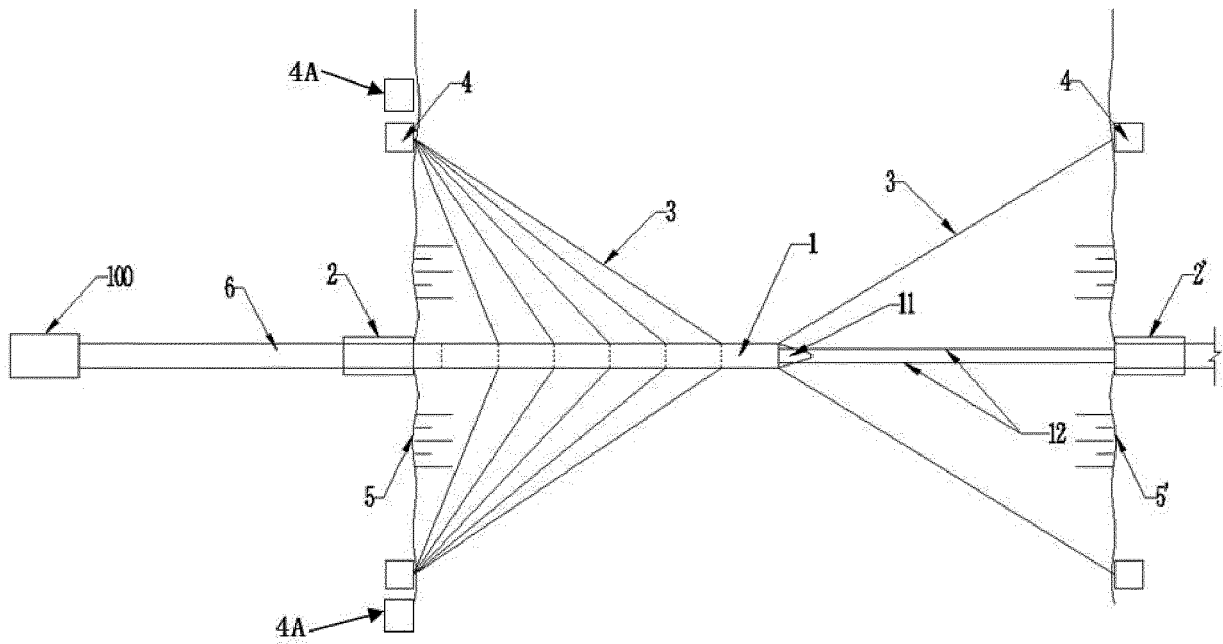


Fig.10

REFERENCES CITED IN THE DESCRIPTION

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