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- **Zheng, Rongping**
Shanghai, 200032 (CN)
- **Zhao, Hui**
Shanghai, 200032 (CN)
- **Sun, Hongchun**
Shanghai, 200032 (CN)
- **Mo, Yasi**
Shanghai, 200032 (CN)
- **Sun, Xu**
Shanghai, 200032 (CN)
- **Zou, Xing**
Shanghai, 200032 (CN)
- **Luo, Hao**
Shanghai, 200032 (CN)

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(71) Applicants:
• **CCCC Third Harbor Engineering Co., Ltd.**
Xu Hui District
Shanghai 200032 (CN)
• **China Communications Construction Company Limited**
100088 Beijing (CN)

(74) Representative: **Clarenbach, Carl-Philipp et al**
Gleiss Große Schrell und Partner mbB
Patentanwälte Rechtsanwälte
Leitzstraße 45
70469 Stuttgart (DE)

(72) Inventors:
• **Xu, Lixin**
Shanghai, 200032 (CN)

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

(57) The present invention discloses an incremental launching process for a submerged cable-stayed floating tunnel. The process includes: prefabricating all the pipe parts of a submerged floating tunnel in a fabrication yard; transporting the pipe parts from a launching-side land slope tunnel into a launching-side shore connection structure, then conducting secondary outfitting, connecting before and after pipe parts and pushing the pipe parts into water in a seal state in turn, and then pushing the pipe parts into a receiving-side shore connection structure; installing stay cables on the pipe parts and pulling them onto cable anchorage piers one by one with the pushing operation; after the pushing operation, pouring concrete on outer surfaces of the pipe parts located in two ends of the submerged floating tunnel in the launching-side shore connection structure and the receiving-side shore connection structure to complete the consolidation of the pipe parts located in two ends of the submerged floating tunnel; and adjusting the buoyancy-weight ratio by adjusting ballast water capacity of each pipe part and sealing-off and covering anchorage. The

incremental launching process of the present invention is less affected by wind, waves, currents, ship waves and so on, thereby reducing the risk of offshore construction greatly, and the present invention has advantages of high construction efficiency and short construction period.

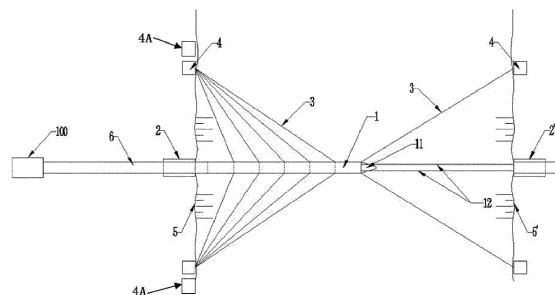


Fig.10

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.

SUMMARY OF THE INVENTION

[0007] 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.

[0008] 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; 5
 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; 10
 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; 15
 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; 20
 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 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; 25
 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; 30
 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 35

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; 40

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; 45

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; 50

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 55

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.

[0009] In Step 5 of above incremental launching process for a submerged cable-stayed floating tunnel, 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.

[0010] In Step 7 and Step 8 of above incremental launching process for a submerged cable-stayed floating tunnel, the first pipe part and the second pipe part are pushed under a wet construction condition.

[0011] In Step 13 of above incremental launching process for a submerged cable-stayed floating tunnel, 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.

[0012] In above incremental launching process for a submerged cable-stayed floating tunnel, 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.

[0013] The incremental launching process for a submerged cable-stayed floating tunnel of the present inven-

tion 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

[0014]

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

[0015] The present invention will be further described below in combination with the drawings.

[0016] 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.

[0017] 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.

[0018] 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.

[0019] 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.

[0020] 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.

[0021] The buoyancy-weight ratio adjustment system is arranged in the water supply and drainage room of each pipe part 10.

[0022] 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 traction 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 structure 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.

[0023] 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.

[0024] 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.

[0025] 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.

[0026] 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.

[0027] 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 loosed 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.

[0028] 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.

[0029] 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.

[0030] 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.

[0031] 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.

[0032] 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.

[0033] 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.

[0034] What are disclosed above are only the preferred embodiments of the present invention, not a limitation to the invention, and therefore for those skilled in prior art, various modifications or changes may be made depending on the specification and the drawings of the present invention without departing from the spirit and scope of the present invention. All equivalent technical solutions will fall into the scope of the present invention and be limited by the appended claims.

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, 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;

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;

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;

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;

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 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; 5
 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. 10

2. The incremental launching process for a submerged cable-stayed floating tunnel as claimed in claim 1, wherein in Step 5, 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. 15 20
3. The incremental launching process for a submerged cable-stayed floating tunnel as claimed in claim 1, wherein in Step 7 and Step 8, the first pipe part and the second pipe part are pushed under a wet construction condition. 25
4. The incremental launching process for a submerged cable-stayed floating tunnel as claimed in claim 1, wherein in Step 13, 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. 30 35
5. The incremental launching process for a submerged cable-stayed floating tunnel as claimed in claim 1, wherein 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. 40 45

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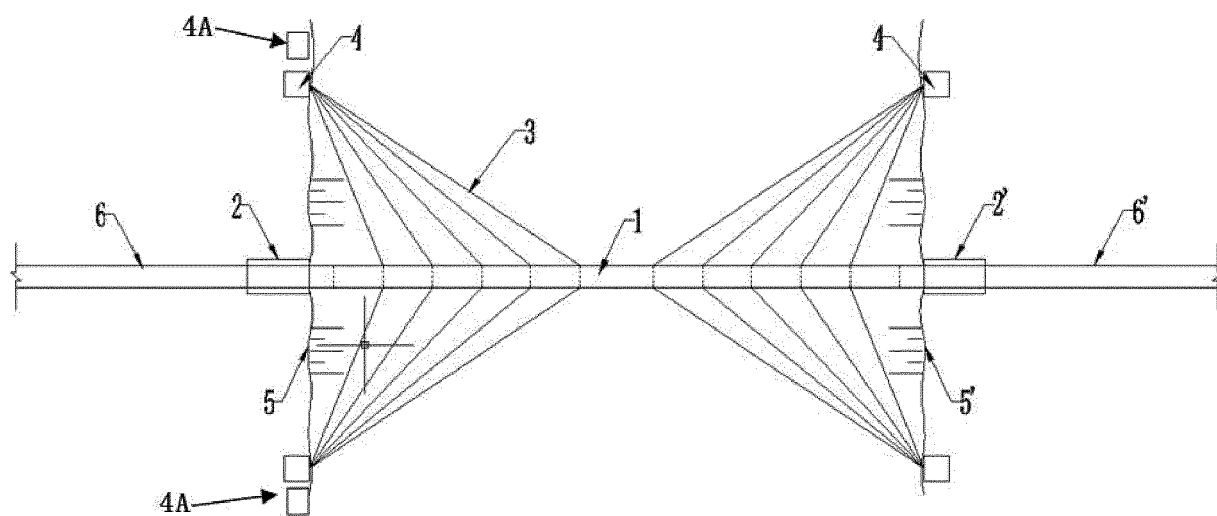


Fig.1

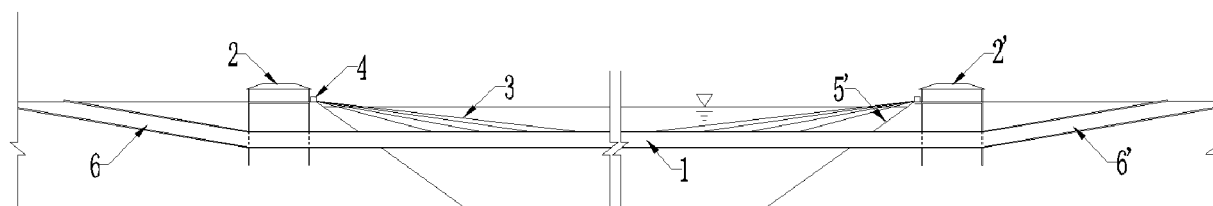


Fig.2

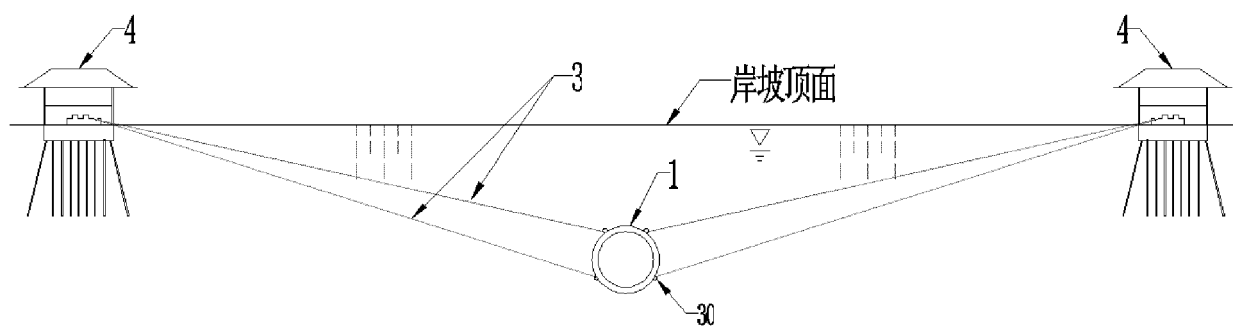


Fig.3

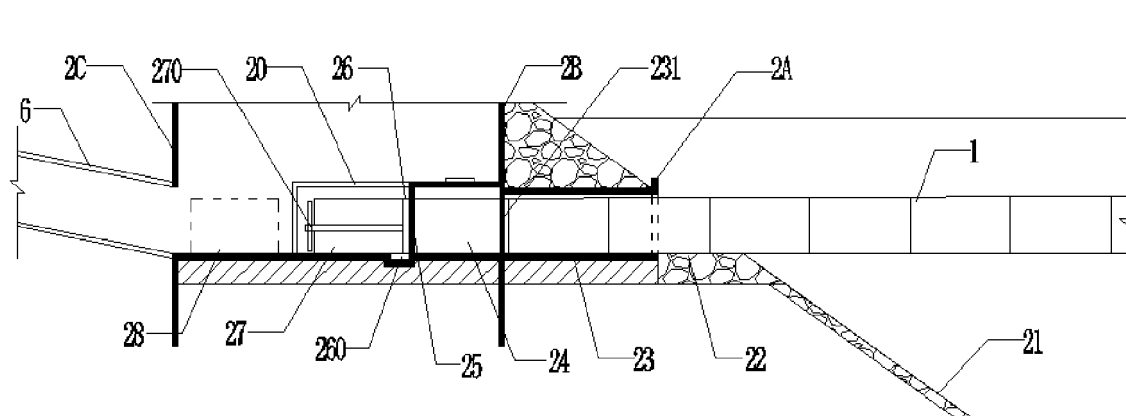


Fig.4

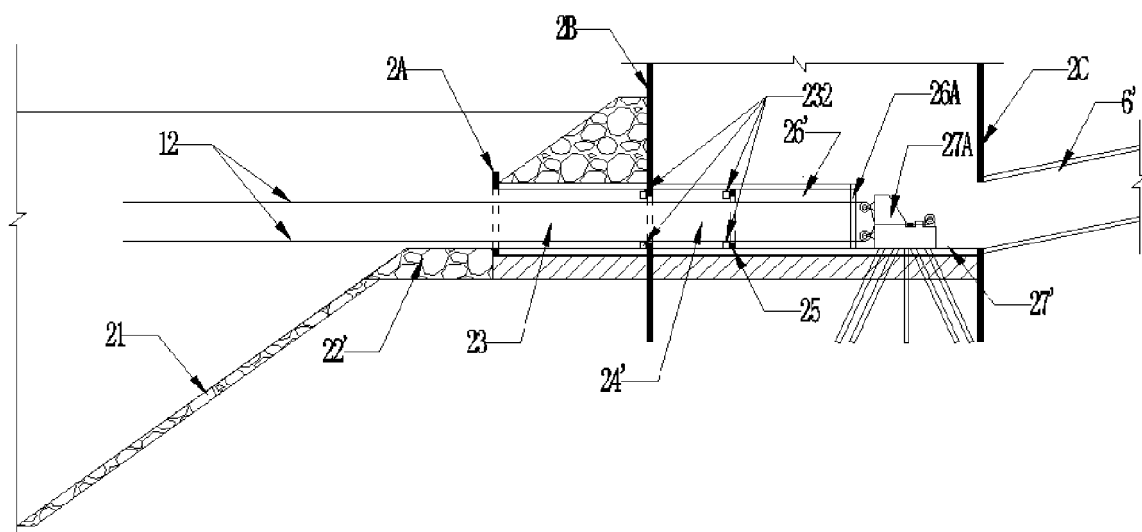


Fig.5

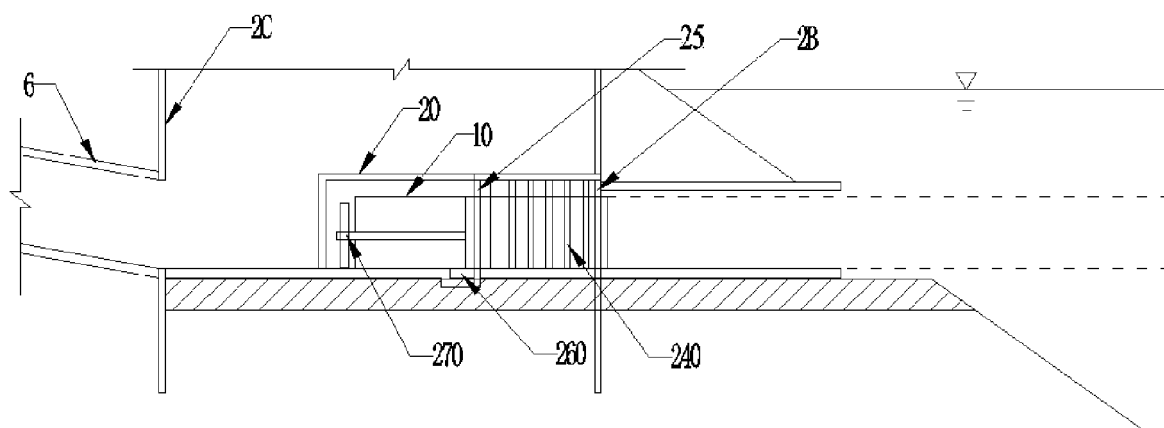


Fig.6

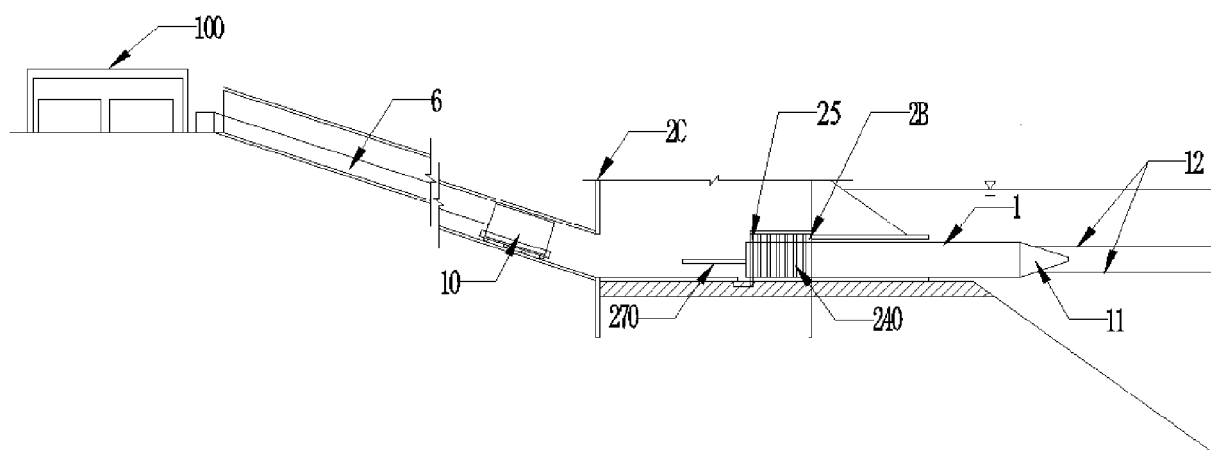


Fig.7

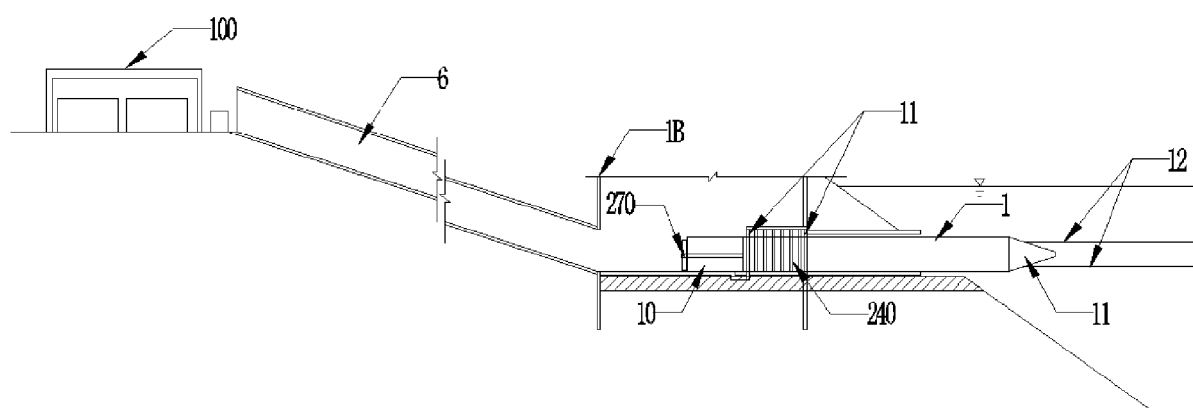


Fig.8

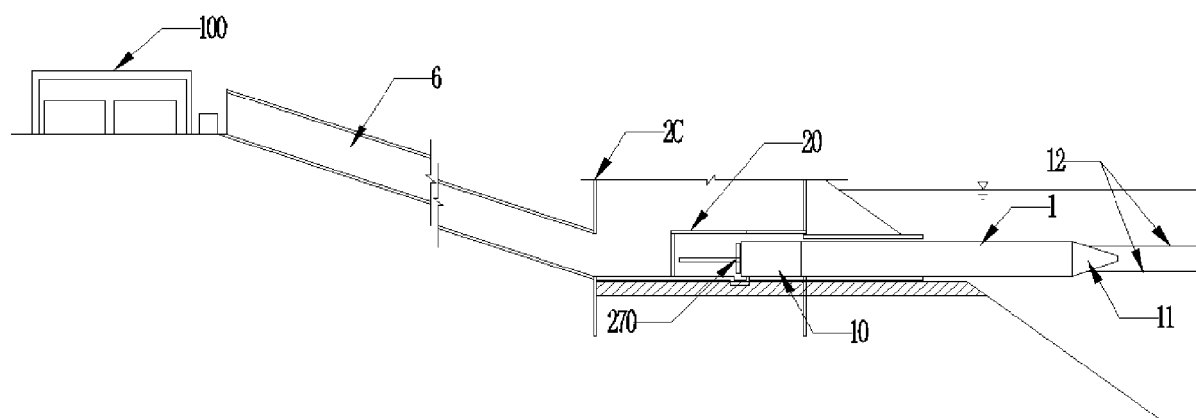


Fig.9

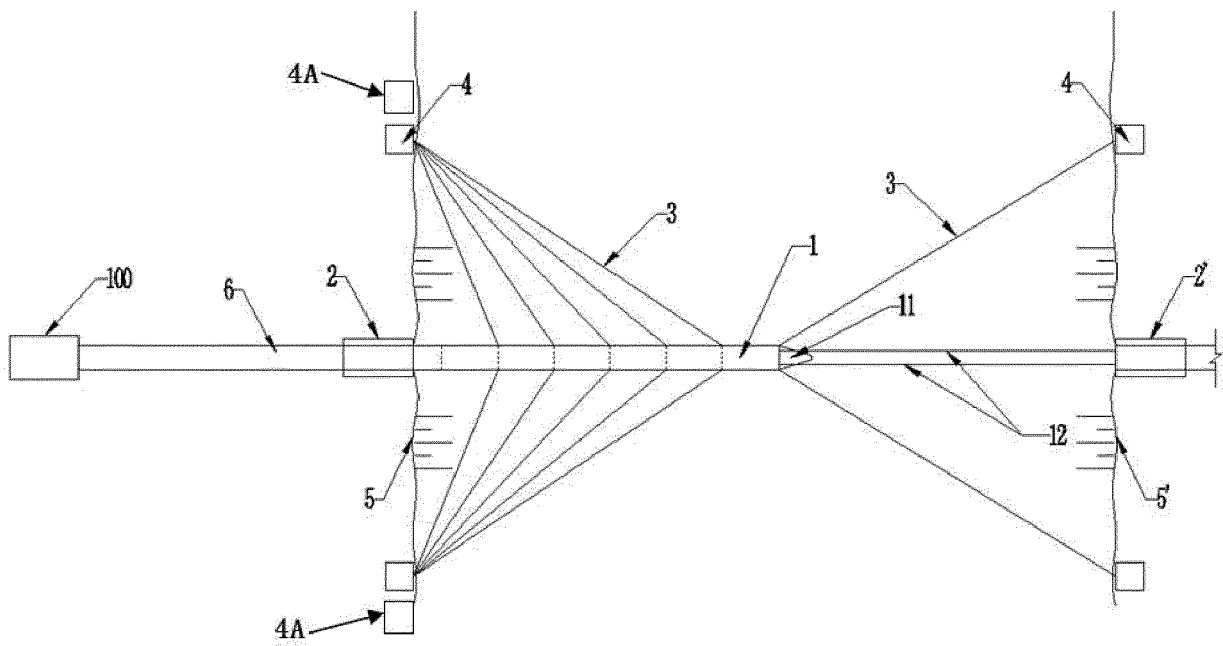


Fig.10



EUROPEAN SEARCH REPORT

Application Number
EP 21 15 2316

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			E02D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 16 August 2021	Examiner Geiger, Harald
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 21 15 2316

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

16-08-2021

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