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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)

(72) Inventors:
- **Xu, Lixin**
  Shanghai, 200032 (CN)
- **Shi, Beiling**
  Shanghai, 200032 (CN)
- **Zhao, Hui**
  Shanghai, 200032 (CN)
- **Sun, Hongchun**
  Shanghai, 200032 (CN)
- **Qiu, Song**
  Shanghai, 200032 (CN)
- **Du, Yu**
  Shanghai, 200032 (CN)
- **Sun, Xu**
  Shanghai, 200032 (CN)
- **Mo, Yasi**
  Shanghai, 200032 (CN)

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

(54) SUBMERGED CABLE-STAYED FLOATING TUNNEL STRUCTURE

(57) Disclose in the present invention is a submerged cable-stayed floating tunnel structure, comprising a submerged floating tunnel, a pair of shore connecting structures, a cable anchor system, a buoyancy-to-weight ratio system adjustment, an anti-collision warning system and an escape system. The pair of shore connecting structures are respectively located on shore slopes on two sides; and the pair of shore connecting structures are respectively connected between two ends of the submerged floating tunnel and a pair of land slope tunnels, the submerged floating tunnel is formed by connecting a plurality of pipe segments; the cable anchor system employs a two-way single cable plane or a two-way double cable plane and comprises four cable receiving shafts, four groups of cable steering piers, cable ramps, and multiple strands of stay cables; the buoyancy-to-weight ratio adjustment system comprises a buoyancy-to-weight ratio adjustment device in a tunnel pipe segments and buoyancy-to-weight ratio adjustment devices in the shore connecting structures; the anti-collision warning system comprises a warning buoy device and a submerged warning anchor cable device; and the escape system comprises an automatic alarm system, an escape time extension system, and escape routes. The submerged cable-stayed floating tunnel structure in the present invention withstands pressure more reasonably, and reduces the impact of adverse sea conditions during construction.

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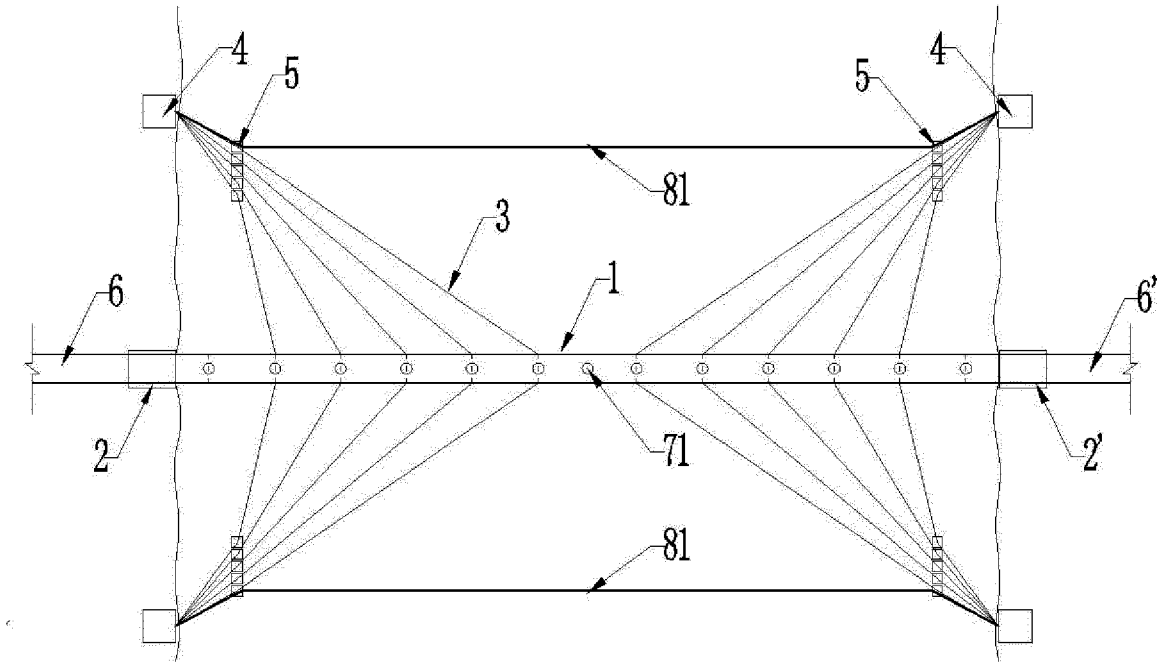

Fig. 1

Description

Field of the Invention

[0001] The present invention relates to a submerged floating tunnel, in particular to a submerged cable-stayed floating tunnel structure.

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 onwater closure, and their comfort and safety risks during underwater operation are difficult to predict.

Summary of the Invention

[0006] The purpose of the present invention is to fill the gaps in the prior art and provide a submerged cable-stayed floating tunnel structure, which withstands pressure more reasonably, reduces the impact of adverse sea conditions during construction, and is more beneficial to control of the construction period and maintenance and parts replacement of the operation period.

[0007] The purpose of the present invention is achieved by providing a submerged cable-stayed floating tunnel structure, which comprises a tunnel body, shore connecting structures, a cable anchor system, a buoyancy-to-weight ratio adjustment system, an anti-collision warning system and an escape system. The shore connecting structures comprise a pushing side shore connecting structure arranged on a pushing side shore and a receiving side shore connecting structure arranged on a receiving side shore in one-to-one correspondence; the tunnel body comprises a submerged floating tunnel, a pushing side land slope tunnel and a receiving side land slope tunnel; a waterfront end of the pushing side

land slope tunnel and a waterfront end of the receiving side land slope tunnel are connected to a backwater end of the pushing side shore connecting structure and a backwater end of the receiving side shore connecting structure in one-to-one correspondence; the submerged floating tunnel is formed by connecting a plurality of pipe parts, and each pipe part is partitioned into a tunnel upper layer, a tunnel middle layer and a tunnel lower layer by an upper partition and a lower partition, the space of the tunnel upper layer being a process chamber; the tunnel middle layer is a tunnel traffic chamber; the tunnel lower layer is a water supply and drainage chamber; wherein, the pushing side shore connecting structure sequentially comprises from the sea to the land: a submerged revetment section, a starting section, a portal section retaining wall, a portal section, a waterfront side wall, a thrust section, a sealing section, a connecting section, a pushing section, a horizontal transportation section and a backwater side wall; the connecting section and the pushing section are arranged in a pipe part connecting box that can be opened and closed; the receiving side shore connecting structure sequentially comprises from the sea to the land: a submerged revetment section, a receiving section, a portal section retaining wall, a portal section, a waterfront side wall, a pipe part stabilizing section, a sealing section, a pipe part consolidation section, a traction anchor section and a backwater side wall;

a plurality of pipe parts of the submerged floating tunnel are connected to a joint water stop material by pipe joints, joint fasteners, and joint fillers; a tail of the last pipe part and a head of the first pipe part are located in the pushing side shore connecting structure and the receiving side shore connecting structure in one-to-one correspondence, and an outer surface of the tail of the last pipe part is consolidated with an inner surface of the pipe part connecting box in the pushing side shore connecting structure by pouring concrete; an outer surface of the head of the first pipe part is consolidated with an inner surface of the pipe part consolidation section in the receiving side shore connecting structure by pouring concrete;

the cable anchor system employs a two-way single cable plane or a two-way double cable plane and comprises four cable receiving shafts, four groups of cable steering piers, cable ramps, and multiple strands of stay cables; the four cable receiving shafts are respectively arranged on the pushing side shores on both sides of the tunnel and receiving side shores on both sides of the tunnel; each cable receiving shaft comprises a cable anchor pier and a monitoring room; the four groups of cable steering piers are respectively arranged on pushing side shore slopes and receiving side shore slopes on both sides of the tunnel and are close to the four cable receiving shafts in one-to-one correspondence; the cable ramp is arranged on the shore slope between each group of cable steering piers and the corresponding cable receiving shaft; one end of the multiple strands of stay cables is anchored at intervals on both sides of the submerged floating tunnel, and the other end of each of the multiple strands of stay cables passes through steering cable guides in the cable steering piers, then extends to the ground along the submerged cable ramps, and is anchored to cable anchor piers;

the buoyancy-to-weight ratio adjustment system comprises a buoyancy-to-weight ratio adjustment device in the tunnel pipe part and buoyancy-to-weight ratio adjustment devices in the shore connecting structures; the buoyancy-to-weight ratio adjustment device in the tunnel pipe part is arranged in the water supply and drainage chamber of each pipe part and comprises a drain device, a water supply device and a water level monitor arranged in the water supply and drainage chamber of each pipe part; the buoyancy-to-weight ratio adjustment devices in the shore connecting structures are arranged in a pushing side pump house of the pushing side shore connecting structure and a receiving side pump house of the receiving side structure; the pushing side pump house is transversely arranged on a side of the connecting section of the pushing side shore connecting structure, and the pushing side pump house is communicated with the water supply and drainage chamber of the last pipe part through a water delivery corridor; the receiving side pump house is transversely arranged on a side of the pipe part consolidation section of the receiving side shore connecting structure, and the receiving side pump house is communicated with the water supply and drainage chamber of the first pipe part through a water delivery corridor;

each of the pushing side water pump room and the receiving side water pump room is divided into a water storage chamber, a water delivery corridor chamber, a water supply valve chamber and a power and monitoring chamber from bottom to top;

the anti-collision warning system comprises a warning buoy device and a submerged warning anchor cable device; and

the escape system comprises an automatic alarm system, an escape time extension system, and escape routes.

[0008] In the above submerged cable-stayed floating tunnel structure, the cross-sectional structure of the submerged floating tunnel is round or prismatic, and the angle of the prismatic tip is less than or equal to 60°.

[0009] In the above submerged cable-stayed floating tunnel structure,

the submerged revetment section of the pushing side shore connecting structure is on a submerged slope on a waterfront side of the shore connecting structure, and rip-raps are provided on the surface of the slope to prevent scouring;

the starting section of the pushing side shore connecting structure is a horizontal section between the portal section retaining wall and a slope top line of the submerged revetment section, and the design elevation of the starting section is a design bottom elevation of a cross section of the submerged floating tunnel to form a pending surface on both shores of the submerged floating tunnel;

the portal section of the pushing side shore connecting

structure is arranged between the portal section retaining wall and the waterfront side wall; the portal section of the pushing side shore connecting structure is further provided with a temporary sealing door and a corresponding water stop device both on the front side of the waterfront side wall; the temporary sealing door is provided with a water blocking plug;

the thrust section of the pushing side shore connecting structure is on the rear side of the waterfront side wall and is of a sealed box structure, the top of the thrust section is provided with a manhole and an embedded cover plate, and a hoop type thrust device is arranged in the thrust section;

the sealing section of the pushing side shore connecting structure is behind the thrust section, the sealing section is a sealing wall with a wall hole, front and rear sides of the sealing wall are respectively provided with a sealing hoop along the circumference of the wall hole, and a water stop strip is arranged between the wall hole and the outer surface of the pipe part;

the connecting section of the pushing side shore connecting structure is behind the sealing section, i.e., at a position which is left and exposed behind the sealing section after the pipe part is pushed forward, and is used to connect with the subsequent pipe part, and the length of the connecting section is the length of part of the pipe part which is left and exposed;

the pushing section of the pushing side shore connecting structure is behind the connecting section, and the bottom of the pushing section is provided with a carrying airbag; a rear part of the pushing section is provided with a pushing trolley in-position section, middle parts of two side walls of the pipe part connecting box are respectively provided with a corbel, the two corbels are respectively provided with a pushing trolley track, and thrust seats are arranged at pipe part connecting positions of the two corbels of the pipe part connecting box;

the horizontal transportation section of the pushing side shore connecting structure is not shorter than each pipe part, and the bottom of the horizontal transportation section is provided with a jacking beam driven by a jack;

the structures of the submerged revetment section, the receiving section, the portal section retaining wall, the portal section, the waterfront side wall, the sealing section and the backwater side wall of the receiving side shore connecting structure are the same as the structures of the submerged revetment section, the starting section, the portal section retaining wall, the portal section, the waterfront side wall, the sealing section and the backwater side wall of the pushing side shore connecting structure in one-to-one correspondence;

the waterfront side wall of the receiving side connecting structure is provided with a wall hole, and a water stop device is arranged on an upstream face of the waterfront side wall and along the wall hole;

the pipe part stabilizing section is behind the waterfront side wall, has a reinforced concrete box structure, and is provided with a hoop type stabilizing device therein;

the sealing section is behind the pipe part stabilizing section, the sealing section is a sealing wall with a wall hole, and a water stop device is also arranged on an upstream face of the sealing wall and along the wall hole;

the pipe part consolidation section is behind the sealing section, has the same structure as the pipe part stabilizing section, and is also of a reinforced concrete box structure, and a steel sealing door is arranged at the tail of the pipe part consolidation section;

the traction anchor section is between the steel sealing door of the pipe part consolidation section and the backwater side wall, a reinforced concrete abutment is arranged at the bottom of the traction anchor section, a pile foundation is arranged below the abutment, and a high-power traction device for a traction cable is arranged on the abutment.

[0010] In the above submerged cable-stayed floating tunnel structure,

the pipe joint is a socket and spigot joint, and an outer surface of a socket and an inner surface of a spigot of each pipe part are uniformly and correspondingly provided with a plurality of countersunk joint bolt holes in the radial direction;

the joint fasteners comprise joint internal fasteners and joint external fasteners; the joint internal fasteners are high-strength stainless steel bolts, nuts and washers inserted in the joint bolt holes and are of a vertical anchoring type; the joint external fasteners comprise a plurality of anchor seats arranged on the inner surface of each pipe part and near an orifice, and steel strands or pre-stressed steel bars connected between the anchor seats of two connected pipe parts by an anchorage device;

the joint fillers comprise a joint gap filler filled between the inner surface of the socket and the outer surface of the spigot of the two connected pipe parts, and a bolt hole filler filled in the joint bolt holes of the two connected pipe parts;

the joint water stop material comprises an outer water stop ring arranged between an end face of the socket and a stop surface of the spigot of the two connected pipe parts, and an inner water stop ring arranged between an end face of the spigot and a stop surface of the socket.

[0011] In the above submerged cable-stayed floating tunnel structure,

the cable anchor pier is arranged at a lower part of the cable receiving shaft; a waterfront side of the cable anchor pier is provided with a cable guide; a middle part of the cable anchor pier is provided with a cable force monitoring groove, a cable force monitor is arranged in the cable force monitoring groove, and an anchor block is arranged at each of two ends of the cable force monitoring groove; an electric windlass is arranged at a rear end of the cable anchor pier; the monitoring room is arranged at an upper part of the cable receiving shaft, and a stay cable monitoring device is arranged in the monitoring room;

each group of cable steering piers is located at the maximum depth of a channel; the number of each group of

cable steering piers is half of the total number of the stay cables; the bottom of each cable steering pier is higher than the elevation of the submerged floating tunnel and not higher than the minimum bottom elevation of the channel; the interior of each cable steering pier is provided with a cable passage along the stay cable, and a steering cable guide is pre-buried in the cable passage.

[0012] In the above submerged cable-stayed floating tunnel structure,

a middle partition wall and two side partition walls are longitudinally arranged in the water supply and drainage chamber of each pipe part; bottoms of the two side partition walls are provided with drain holes at intervals; a middle cross partition wall is further arranged at a longitudinal middle part in the water supply and drainage chamber of each pipe part, and an end cross partition wall is arranged at each of two ends of the water supply and drainage chamber of each pipe part, so that the water supply and drainage chamber of each pipe part is partitioned into four middle compartments and four side compartments; an overflow passage is arranged at the top of each of the middle cross partition wall and the two end cross partition walls;

the drain device comprises a group of drain pipes and a group of submersible pumps; the drain pipes are longitudinally arranged at upper parts of both sides of the middle partition wall, and starting points of the drain pipes are at the longitudinal middle part of each pipe part; the submersible pumps are at bottoms of the middle compartments corresponding to the starting points of the drain pipes, and the submersible pumps are connected to the drain pipes through water outlet hoses in one-to-one correspondence;

the water supply device comprises a group of water supply pipes respectively longitudinally arranged at upper parts of outer sides of the two side partition walls;

the water level monitor is arranged on one side of the middle partition wall;

the maximum water storage capacity of the water storage chamber is the water capacity of the water supply and drainage chambers of two pipe parts, and a water gauge for metering is arranged on a wall of the water storage chamber; tail ends of the drain pipes in the water supply and drainage chamber are connected to the water storage chamber; a water supply pump, a drain pump, an external drain pipe, and an external water supply pipe are arranged in the water storage chamber; the water supply pump is connected to a tail end of the water supply pipe in the water supply and drainage chamber; the drain pump is connected to the external drain pipe for draining excessive water to the outside of the water storage chamber; the external water supply pipe is used to supply water to the water storage chamber;

the water delivery corridor chamber is as high as the water delivery corridor;

the height of the water supply valve chamber is not less than 2.0 m, and a water supply valve and a water meter are arranged in the water supply valve chamber;

the height of the power and monitoring chamber is not less than 2.8 m, and a power motor and computer monitoring equipment are arranged in the power and monitoring chamber.

[0013] In the above submerged cable-stayed floating tunnel structure,

the warning buoy device comprises a plurality of buoys, a plurality of fixed cables and a plurality of warning lights; a plurality of buoys are arranged on the water surface above the submerged floating tunnel at intervals along an axis of the submerged floating tunnel; a plurality of fixed cables are fixed between a plurality of buoys and the submerged floating tunnel in one-to-one correspondence; a plurality of warning lights are attached to tops of a plurality of buoys in one-to-one correspondence;

the submerged warning anchor cable device comprises two submerged warning cables, a plurality of slings and a plurality of warning light strips; the two submerged warning cables are arranged in parallel on both sides of the submerged floating tunnel; pushing side shore ends of the two submerged warning cables respectively penetrate through the two groups of cable steering piers arranged on the pushing side shore, then extend to the ground along the cable ramps, and are anchored to the two cable anchor piers arranged on the pushing side shore, and receiving side shore ends of the two submerged warning cables respectively penetrate through the two groups of cable steering piers arranged on the receiving side shore, then extend to the ground along the cable ramps, and are anchored to the two cable anchor piers arranged on the receiving side shore; a plurality of slings are hung on the two submerged warning cables at intervals; a plurality of warning light strips are mounted on a plurality of slings in one-to-one correspondence.

[0014] In the above submerged cable-stayed floating tunnel structure,

the automatic alarm system comprises a video monitoring device, water level monitoring devices, a temperature measurement and control device, a toxic gas detection device and centralized control centers; the video monitoring device, the temperature measurement and control device and the toxic gas detection device are all arranged at the top of the tunnel upper layer; the water level monitoring devices are arranged in the water supply and drainage chamber of each pipe part, the water delivery corridor of the pushing side shore connecting structure, the pushing side pump house, the water delivery corridor of the receiving side shore connecting structure, and the receiving side pump house; the centralized control centers are arranged in the pushing side shore connecting structure and the receiving side shore connecting structure;

the escape time extension system comprises a buoyancy-to-weight ratio adjustment system, contact passage sealing doors and tunnel portal emergency sealing doors; the contact passage sealing doors are arranged at both ends of a contact passage of the double-pipe tunnel;

the tunnel portal emergency sealing doors are arranged

at a tunnel exit of the pushing side shore connecting structure and a tunnel exit of the receiving side shore connecting structure;

the escape routes comprise an escape route in the tunnel and an escape route at the top of the tunnel; the escape route in the tunnel comprises a tunnel pavement escape passage and a tunnel upper layer escape passage leading to the pushing side shore connecting structure and the receiving side shore connecting structure, and the contact passage of the double-pipe tunnel; the tunnel pavement escape passage is arranged in the tunnel middle layer; the tunnel upper layer escape passage is arranged at the tunnel upper layer and is entered through a plurality of manholes formed in the upper partition; the escape route at the top of the tunnel comprises a plurality of spare emergency escape exits arranged and rescue submarines at the top of the tunnel; an emergency hatch door is arranged on each spare emergency escape exit; the rescue submarine is docked at the top of the emergency hatch door, and the bottom of the rescue submarine is provided with a spare emergency hatch connected with the emergency hatch door.

[0015] In the above submerged cable-stayed floating tunnel structure, the pushing side land slope tunnel and the receiving side land slope tunnel are both provided with an open trench tunnel and a tunnel according to the mine tunneling method in sequence downwards from the ground; and the open trench tunnel is provided with an open section, a grating section and a buried section downwards from the ground.

[0016] The submerged cable-stayed floating tunnel structure of the present invention has the following characteristics:

1) The cable-stayed floating tunnel of the present invention has a simple linear structure, and the submerged floating tunnel has the shortest total length and is lower in cost than a curved floating tunnel.

2) The cable-stayed floating tunnel of the present invention is completely underwater, and will not affect the passage of ships on the water surface.

3) The total height of the cable-stayed floating tunnel of the present invention is only the height difference between the elevation of a turning point of a stay cable in the middle of a cable-stayed steering pier and the elevation of a bottom surface of a pipe part. The underwater space occupied by the stay cable is smaller than that in the pontoon type, anchored type and pier type floating tunnels proposed internationally so far, thereby reducing the range of influence on an underwater submersible.

4) Compared with the anchored type floating tunnel in an ultra-deep water area, the total length of the stay cable of the cable-stayed floating tunnel in the present invention is much smaller, and the cost is correspondingly lower.

5) Compared with the pontoon type floating tunnel, the cable-stayed floating tunnel of the present invention is not affected by tide rises and falls, and withstands pressure more reasonably and more clearly.

6) The stay cable is guided to the ground can be used for positioning when the submerged floating tunnel is installed, and the land control makes the actual operation very convenient and provides a convenient limit device and method for the installation of the submerged floating tunnel.

7) The stay cable of the present invention can be used for monitoring of cable force and maintenance and replacement of the cable during the operation period of the tunnel, while the anchor system of the anchored type floating tunnel is underwater, which makes the maintenance and replacement extremely difficult.

8) The stay cable of the present invention provides an upward force to the submerged floating tunnel, so that the submerged floating tunnel never sinks, which greatly reduces the safety risk during the operation period of the tunnel.

Brief Description of the Drawings

[0017]

Fig. 1 is a plan view of a submerged cable-stayed floating tunnel structure according to the present invention;

Fig. 2 is a longitudinal sectional view of the submerged cable-stayed floating tunnel structure according to the present invention;

Fig. 3 is a cross-sectional view of the submerged cable-stayed floating tunnel structure with a two-way single cable plane according to the present invention;

Fig. 4 is a cross-sectional view of the submerged cable-stayed floating tunnel structure with a two-way double cable plane according to the present invention;

Fig. 5 is a longitudinal sectional view of a pushing side shore connecting structure in the submerged cable-stayed floating tunnel structure according to the present invention;

Fig. 6 is a cross-sectional view of a thrust section of the pushing side shore connecting structure in the submerged cable-stayed floating tunnel structure according to the present invention;

Fig. 7 is a cross-sectional view of a pushing section of the pushing side shore connecting structure in the submerged cable-stayed floating tunnel structure according to the present invention;

Fig. 8 is a longitudinal sectional view of a receiving side shore connecting structure in the submerged cable-stayed floating tunnel structure according to the present invention;

Fig. 9 is a longitudinal sectional view of a pipe part connection in the submerged cable-stayed floating tunnel structure according to the present invention;

Fig. 10 is a transverse sectional view of a pipe part connection in the submerged cable-stayed floating tunnel structure according to the present invention;
Fig. 11 is a transverse sectional view of a fixed connection between the last pipe part in the submerged cable-stayed floating tunnel structure and the pushing side shore connecting structure according to the present invention;
Fig. 12 is a longitudinal sectional view of a fixed connection between the last pipe part in the submerged cable-stayed floating tunnel structure and the pushing side shore connecting structure according to the present invention;
Fig. 13 is a schematic structural diagram of a cable receiving shaft in the submerged cable-stayed floating tunnel structure according to the present invention;
Fig. 14 is a schematic structural diagram of a cable anchor pier in the submerged cable-stayed floating tunnel structure according to the present invention;
Fig. 15 is a schematic structural diagram of a cable steering pier in the submerged cable-stayed floating tunnel structure according to the present invention;
Fig. 16 is a transverse sectional view of a buoyancy-to-weight ratio adjustment device in the tunnel pipe part of the submerged cable-stayed floating tunnel structure according to the present invention;
Fig. 17 is a longitudinal sectional view of the buoyancy-to-weight ratio adjustment device in the tunnel pipe part of the submerged cable-stayed floating tunnel structure according to the present invention;
Fig. 18 is a longitudinal sectional view of a buoyancy-to-weight ratio adjustment device in the shore connecting structure of the submerged cable-stayed floating tunnel structure according to the present invention;
Fig. 19 is a plane view of the buoyancy-to-weight ratio adjustment device in the shore connecting structure of the submerged cable-stayed floating tunnel structure according to the present invention;
Fig. 20 is a cross-sectional view of a contact passage of a double-pipe tunnel in an escape system of the submerged cable-stayed floating tunnel structure according to the present invention;
Fig. 21 is a longitudinal sectional view of a tunnel upper layer escape passage in the escape system of the submerged cable-stayed floating tunnel structure according to the present invention;
Fig. 22 is a cross-sectional view of a tunnel top escape route in the escape system of the submerged cable-stayed floating tunnel structure according to the present invention.

Detailed Description of the Embodiments

[0018] The present invention will be further illustrated below in conjunction with the accompanying drawings.

[0019] Referring to Fig. 1 to Fig. 22, a submerged cable-stayed floating tunnel structure of the present invention includes a tunnel body, shore connecting structures, a cable anchor system, a buoyancy-to-weight ratio adjustment system, an anti-collision warning system, an escape system and auxiliary facilities of the tunnel. The shore connecting structures include a pushing side shore connecting structure 2 arranged on a pushing side shore and a receiving side shore connecting structure 2'arranged on a receiving side shore in one-to-one correspondence; the tunnel body includes a submerged floating tunnel 1, a pushing side land slope tunnel 6 and a receiving side land slope tunnel 6'; and a waterfront end of the pushing side land slope tunnel 6 and a waterfront end of the receiving side land slope tunnel 6' are connected to a backwater end of the pushing side shore connecting structure 2 and a backwater end of the receiving side shore connecting structure 2' in one-to-one correspondence. The cross-sectional structure of the submerged floating tunnel 1 is round or prismatic, and the angle of the prismatic tip is less than or equal to 60°; the pushing side land slope tunnel 6 and the receiving side land slope tunnel 6' are both provided with an open trench tunnel and a tunnel according to the mine tunneling method in sequence downwards from the ground; and the open trench tunnel is provided with an open section, a grating section and a buried section downwards from the ground. The submerged floating tunnel 1 is formed by connecting a plurality of pipe parts 10, and each pipe part 10 is partitioned into a tunnel upper layer 10A, a tunnel middle layer 10B and a tunnel lower layer 10C by an upper partition 10 and a lower partition 1B, and the space of the tunnel upper layer 10A is a process chamber; the tunnel middle layer 10B is a tunnel traffic chamber; and the tunnel lower layer 10C is a water supply and drainage chamber.

[0020] The pushing side shore connecting structure 2 sequentially includes from the sea to the land: a submerged revetment section 21, a starting section 22, a portal section retaining wall 2A, a portal section 23, a waterfront side wall 2B, a thrust section 24, a sealing section 25, a connecting section 26, a pushing section 27, a horizontal transportation section 28 and a backwater side wall 2C; wherein

[0021] The submerged revetment section 21 is on a submerged slope on a waterfront side of the pushing side shore connecting structure 2, and the slope is protected by rip-raps to prevent scouring; and the protection length of the slope is designed according to an overall arc sliding surface from the backwater side wall 2C to the submerged revetment section 21.

[0022] The starting section 22 is a horizontal section between the portal section retaining wall 2A and a slope top line of the submerged revetment section 21, and the design elevation of the starting section 22 is a design bottom elevation of a cross section of the submerged floating tunnel 1 to form a pending surface on both shores of the submerged floating tunnel 1, which creates a condition for achieving the purpose of never sinking of the

submerged floating tunnel 1; a tunnel bed of the starting section 22 is formed after excavation of a partial shore slope, and a top surface of the bed is composed of a gravel cushion and block stones; a high-pressure water gun is further arranged on the top surface of the bed to prevent bulge caused by siltation; and in order to ensure the stability of shore slopes on both sides of the wall outside tunnel, a tunnel top of the starting section 22 is backfilled with block stones 220. When the length of the starting section 22 is designed, the overall arc sliding stability requirements of the submerged slope of the shore connecting structure must be first met. In addition, the width of the outer shore slope top of the shore connecting structure needs to meet the width requirements of construction of an enclosing structure, so the length of the starting section 22 is 10m-12m;

[0023] Protective guide walls on both sides of the wall outside tunnel of the starting section 22 are designed and calculated as a cantilever structure; the range of width of the shore slope top can use a ground connection wall structure, and the outside is protected by steel pipe locking piles;

[0024] The portal section 23 is arranged between the portal section retaining wall 2A and the waterfront side wall 2B, the portal diameter of the portal section 23 is the outer diameter of the pipe part + 2 $\times$ the diameter of a stay cable + a rich gap, and the rich gap is 6-10cm.

[0025] The portal section 23 of the pushing side shore connecting structure 2 is further provided with a temporary sealing door 231 and a corresponding water stop device both on the front side of the waterfront side wall 2B, the temporary sealing door 231 is provided with a water blocking plug, and the temporary sealing door 231 is fastened by means of deep water pressure outside the waterfront side wall 2B; when pushing, the water blocking plug is opened to balance the internal and external water pressure, and the temporary sealing door 231 can be opened easily; the temporary sealing door 231 is a steel sealing door and has a diameter of the portal diameter + 100 cm;

[0026] The thrust section 24 is on the rear side of the waterfront side wall 2B and is of a sealed box structure, and the thrust section 24 has a length of 60m-80m; the top of the thrust section 24 is provided with a manhole 240 and an embedded cover plate for maintenance; a hoop type thrust device 241 is arranged in the thrust section 24, and thrust is achieved by means of friction between the hoop type thrust device 241 and the pipe part 10;

[0027] The sealing section 25 is behind the thrust section 24 and is used to temporarily stop water during dry and wet environment switching after the pipe part 10 is pushed; in order to achieve a better sealing effect and withstand higher deep water pressure, the sealing section 25 is a sealing wall with a wall hole; after the previous pipe part 10 is pushed, its tail end is left in the sealing wall for connecting with the subsequent pipe part 10; front and rear sides of the sealing wall 25 are respectively provided with a sealing hoop along the circumference of the wall hole, and a water stop strip is arranged between the wall hole and the outer surface of the pipe part 10;

[0028] The connecting section 26 is behind the sealing section 25, i.e., at a position which is left and exposed behind the sealing section after the pipe part 10 is pushed forward, and is used to connect with the subsequent pipe part, and the length of the connecting section 26 is the length of part of the pipe part 10 which is left and exposed; the length of the connecting section 26 is 100cm-120 cm, and the bottom of the connecting section 26 is provided with a stepped pipe part connecting pit 260 for personnel standing. The pipe part connecting pit 260 has a width of 1 m and a depth of 1.5 m;

[0029] The connection of the pipe part 10 of the submerged floating tunnel 1 is constructed in a dry environment, so in order to form the dry environment, the connecting section 26 and the pushing section 27 are both arranged in a pipe part connecting box 2D that can be opened and closed, so that the pipe part connecting box 2D can be designed as a rectangular water tank with a top cover, and the pipe part connecting box 2D is reserved with pedestrian passages having widths of 60 to 100 cm on both sides of the pipe part 10, and reserved with a clear height of 100 to 120 cm at a bottom; high-power pumping equipment is arranged in the pipe part connecting box 2D, and after the pipe part 10 is pushed, thrust and sealed, water is pumped in the pipe part connecting box 2D to form the dry environment. In order to facilitate the connection and tensioning of the pipe part 10, a pull ring is arranged on the wall of the connecting section 26 of the pipe part connecting box 2D, or an anchor is arranged at a rear end of the pushing section 27;

[0030] The pushing section 27 is behind the connecting section 26, and is used for connecting, tensioning and pushing the pipe part 10; the bottom of the pushing section 27 is provided with a carrying airbag; to facilitate pushing of the pipe part 10, a rear part of the pushing section 27 is provided with a pushing trolley in-position section, middle parts of two side walls of the pipe part connecting box 2D are respectively provided with a corbel 271, the two corbels 271 are respectively provided with a pushing trolley track 272 on which a pushing trolley 270 moves forward, and thrust seats for limiting the pushing trolley 270 are arranged at pipe part connecting positions of the two corbels 271 of the pipe part connecting box 2D; the length of the pushing section 27 is the sum of the length of each section pipe part 10 and the length of the pushing trolley in-position section;

[0031] The horizontal transportation section 28 is not shorter than each pipe part 10; the horizontal transportation section 28 is used to transport the pipe part 10 from the pushing side land slope tunnel 6 to the pushing side shore connecting structure 2 for slope switching, pipe part unloading and secondary outfitting, and can be used as a station platform and a meeting transit area during the operation period of the floating tunnel; to facilitate the secondary outfitting of the tunnel pipe part 10, a trans-

portation flat car for the pipe part 10 can be directly driven to the horizontal transportation section 28; the bottom of the horizontal transportation section 28 is provided with a jacking beam driven by a jack, and after the jacking beam is lifted, the transportation flat car exits for the secondary outfitting; after the secondary outfitting is completed, the carrying airbag is inserted between the lower part of the pipe part 10 and the jacking beam, and after the carrying airbag is inflated, the pipe part 10 is moved to the pushing section 27 for connecting.

[0032] The receiving side shore connecting structure 2' sequentially includes from the sea to the land: a submerged revetment section 21, a receiving section 22', a portal section retaining wall 2A, a portal section 23, a waterfront side wall 2B, a pipe part stabilizing section 24', a sealing section 25, a pipe part consolidation section 26', a traction anchor section 27' and a backwater side wall 2C, wherein

[0033] The structures of the submerged revetment section 21, the receiving section 22', the portal section retaining wall 2A, the portal section 23, the waterfront side wall 2B, the sealing section 25 and the backwater side wall 2C of the receiving side shore connecting structure 2' are the same as the structures of the submerged revetment section 21, the starting section 22, the portal section retaining wall 2A, the portal section 23, the waterfront side wall 2B, the sealing section 25 and the backwater side wall 2C of the pushing side shore connecting structure 2 in one-to-one correspondence; and the pipe part stabilizing section 24', the pipe part consolidation section 26' and the traction anchor section 27' are similar to the thrust section 24, the pushing section 27 and the horizontal transportation section 28 in the pushing side shore connecting structure 2 in one-to-one correspondence, and their longitudinal lengths can be reduced.

[0034] The waterfront side wall 2B of the receiving side connecting structure 2' is provided with a wall hole for jacking the pipe part 10, a water stop device 232 is arranged on an upstream face of the waterfront side wall 2B and along the wall hole, the water stop device 232 is a sealing hoop, and a rubber water stop strip is mounted on the sealing hoop.

[0035] The pipe part stabilizing section 24' is behind the waterfront side wall 2B and is of a reinforced concrete box structure, with a manhole and an embedded cover plate provided at the top thereof. A hoop type pipe part stabilizing device for controlling the stability of posture after the pipe part 10 is pushed in is arranged in the pipe part stabilizing section 24'.

[0036] The sealing section 25 is behind the pipe part stabilizing section 24', the sealing section 25 is a sealing wall with a wall hole, a water stop device 232 is also arranged on an upstream face of the sealing wall and along the wall hole, the water stop device 232 is a sealing hoop, and a rubber water stop strip is mounted on the sealing hoop.

[0037] The pipe part consolidation section 26' is behind the sealing section 25, has the same structure as the pipe part stabilizing section 24', and is also of a reinforced concrete box structure. A steel sealing door 26A is arranged at the tail of the pipe part consolidation section 26', and forms a sealed cabin structure together with the pipe part consolidation section 26' to prevent seawater intrusion. After the pipe part 10 is pushed into the pipe part consolidation section 26', the water stop device 232 on the waterfront side wall 2B and the water stop device 232 on the sealing section 25 are opened, then water is pumped from the pipe part consolidation section 26' to form a dry construction environment, and concrete is poured on an outer surface of a head of the pipe part 10 in the pipe part consolidation section 26'to consolidate with the receiving side shore connecting structure 2'.

[0038] The traction anchor section 27' is between the steel sealing door 26A of the pipe part consolidation section 26' and the backwater side wall 2C, a reinforced concrete abutment is arranged at the bottom of the traction anchor section 27', a pile foundation is arranged below the abutment, and a high-power traction device 27A for a traction cable 12 is arranged on the abutment. After the pipe part is pushed in place and consolidated, the abutment and the traction device 27A are removed, and then the head of the first pipe part is communicated with the receiving side land slope tunnel 6' by cast-in-place reinforced concrete.

[0039] The pushing side shore connecting structure and the receiving side shore connecting structure of the present invention can be used as transfer stations during operation of the floating tunnel, and can also be used as a starting shaft for the construction of the land slope tunnel, and the buoyancy-to-gravity ratio of the floating tunnel is adjusted during construction and operation, so the application is wide. Both the pushing side shore connecting structure and the receiving side shore connecting structure are underground reinforced concrete structures with pile foundations under the foundation to increase vertical and horizontal bearing capacities. According to the geological conditions, the pushing side shore connecting structure and the receiving side shore connecting structure may be constructed by a ground connection wall reverse construction method, a sinking shaft method or a freezing method; and the portal sections of the pushing side shore connecting structure and the receiving side shore connecting structure are constructed by a cofferdam method.

[0040] A plurality of pipe parts 10 of the submerged floating tunnel 1 are connected to a joint water stop material by pipe joints, joint fasteners, and joint fillers, wherein

[0041] The pipe joint is a socket and spigot joint, and an outer surface of a socket and an inner surface of a spigot of each pipe part 10 are uniformly and correspondingly provided with a plurality of countersunk joint bolt holes in the radial direction;

[0042] The joint fasteners include joint internal fasteners and joint external fasteners; the joint internal fasteners are high-strength stainless steel bolts 11, nuts and

washers inserted in the joint bolt holes and are of a vertical anchoring type; the joint external fasteners include a plurality of anchor seats 12 arranged on the inner surface of each pipe part 10 and near an orifice, and steel strands or pre-stressed steel bars 13 connected between the anchor seats 12 of two connected pipe parts by an anchorage device;

[0043] The joint fillers include a joint gap filler 14 filled between the inner surface of the socket and the outer surface of the spigot of the two connected pipe parts 10, and a bolt hole filler (not shown) filled in the joint bolt holes of the two connected pipe parts 10;

[0044] The joint water stop material includes an outer water stop ring 15 arranged between an end face of the socket and a stop surface of the spigot of the two connected pipe parts 10, and an inner water stop ring 16 arranged between an end face of the spigot and a stop surface of the socket.

[0045] A tail of the last pipe part 10' and a head of the first pipe part are located in the pushing side shore connecting structure 2 and the receiving side shore connecting structure 2' in one-to-one correspondence, and an outer surface of the tail of the last pipe part 10' is consolidated with an inner surface of the pipe part connecting box 2D in the pushing side shore connecting structure 2 by pouring concrete 20'; and an outer surface of the head of the first pipe part is consolidated with an inner surface of the pipe part consolidation section 26' in the receiving side shore connecting structure 2' by pouring concrete.

[0046] The vertical anchorage of the joint internal fastening bolts used in the present invention is more reliable than the anchorage of horizontal bolt threads; the joint external fasteners, i.e., external pre-stressed structures, can be used not only for tensioning when the pipe parts are connected, but also can bear horizontal tension during the operation period of the tunnel; and therefore, the joint fasteners can not only meet the requirements of an underwater jacking installation process for the pipe parts of the submerged floating tunnel, but also meet the requirements of the tunnel structure for pressure standing and durability.

[0047] The cable anchor system employs a two-way single cable plane or a two-way double cable plane and includes four cable receiving shafts 4, four groups of cable steering piers 5, cable ramps 50, and multiple strands of stay cables 3; wherein

[0048] The four cable receiving shafts 4 are respectively arranged on the pushing side shores on both sides of the tunnel and receiving side shores on both sides of the tunnel; each cable receiving shaft 4 includes a cable anchor pier 40 and a monitoring room; the cable anchor pier 40 is arranged at a lower part of the cable receiving shaft 4; a waterfront side of the cable anchor pier 40 is provided with a cable guide 41; a middle part of the cable anchor pier 40 is provided with a cable force monitoring groove 42, a cable force monitor 43 is arranged in the cable force monitoring groove 42, and an anchor block is arranged at each of two ends of the cable force monitoring groove 42; an electric windlass 44 is arranged at a rear end of the cable anchor pier 40; the monitoring room is arranged at an upper part of the cable receiving shaft 4, and a stay cable monitoring device 45 is arranged in the monitoring room; a rear side of each cable receiving shaft 4 is further provided with a power station 46;

[0049] The four groups of cable steering piers 5 are respectively arranged on pushing side shore slopes on both sides of the tunnel and receiving side shore slopes on both sides of the tunnel and are close to the four cable receiving shafts 4 in one-to-one correspondence; each group of cable steering piers 5 is located at the maximum depth of a channel; the number of each group of cable steering piers 5 is half of the total number of the stay cables 3; the bottom of each cable steering pier 5 is higher than the elevation of the submerged floating tunnel 1 and not higher than the minimum bottom elevation of the channel; the interior of each cable steering pier 5 is provided with a cable passage along the stay cable 3, and a steering cable guide 51 is pre-buried in the cable passage;

[0050] The cable ramp 50 is arranged on the shore slope between each group of cable steering piers 5 and the corresponding cable receiving shaft 4;

[0051] Half of the multiple strands of stay cables 3 are pushing side stay cables, and the other half are receiving side stay cables; if a two-way single cable plane is used, each strand of stay cables 3 includes two stay cables connected to both sides of the submerged floating tunnel 1; if a two-way double cable plane is used, each strand of stay cables 3 includes four stay cables respectively connected in two pairs to both sides of the submerged floating tunnel 1; one end of the pushing side stay cables 3 is anchored at intervals to cable anchors 30 on outer surfaces of both sides of the submerged floating tunnel 1 with half the length near the pushing side shore, and the other end of each of the pushing side stay cables 3 respectively passes through the two groups of cable steering piers 5 arranged on the pushing side shore, then extends to the ground along the cable ramps 50, and is anchored to the two cable anchor anchors 40 arranged on the pushing side shore; one end of the receiving side stay cables 3 is anchored at intervals to cable anchors 30 on outer surfaces of both sides of the submerged floating tunnel 1 near the receiving side shore, and the other end of each of the receiving side stay cables 3 respectively passes through the two groups of cable steering piers 5 arranged on the receiving side shore, then extends to the ground along the cable ramps 50, and is anchored to the two cable anchor anchors 40 arranged on the receiving side shore.

[0052] The cable anchor system of the present invention adopts the cable anchor piers 40 upward on the shores, and the stay cables 3 is underwater, and is thus not affected by tide rises and falls. The ratio of the buoyancy of the submerged floating tunnel 1 to its gravity (buoyancy-to-gravity ratio) is less than 1, and near 1, to maintain its floating depth. The stay cables bear the hor-

izontal and vertical loads on the pipe part, and also bear horizontal forces such as water flow force. The cable anchor system of the present invention can be used for positioning of the submerged floating tunnel 1 when the pipe part of the tunnel is mounted; and can also be used for monitoring of cable force and maintenance and replacement of the stay cables during the operation period of the tunnel. The cable steering pier 5 must be located on a stable foundation within the shore slope to meet the requirements of slope stability. The cable steering pier 5 is of a reinforced concrete pier structure with a pile foundation underneath to increase the pull-out resistance and the stability of the shore slope. The cable ramp 50 not only prevents the stay cable 3 from being worn, but also protects the shore slope. The structure of the cable ramp 50 includes a rip-rap revetment, a gravel cushion and a concrete surface layer. The cable anchor pier 40 must be located on a stable foundation on the ground of the shore and meet the requirements of slope stability. The cable anchor pier 40 is of a reinforced concrete pier structure with a pile foundation underneath to increase the pull-out resistance and the stability of the shore slope. The cable steering pier 5, the cable ramp 50, and the cable anchor pier 40 may be constructed by a cast-in-place method in a cofferdam.

[0053] The buoyancy-to-weight ratio adjustment system includes a buoyancy-to-weight ratio adjustment device in the tunnel pipe part and buoyancy-to-weight ratio adjustment devices in the shore connecting structures.

[0054] The buoyancy-to-weight ratio adjustment device in the tunnel pipe part is arranged in the water supply and drainage chamber 10C of each pipe part and includes a drain device, a water supply device and a water level monitor 17 arranged in the water supply and drainage chamber 10C of each pipe part; wherein

[0055] A middle partition wall 171 and two side partition walls 172 are longitudinally arranged in the water supply and drainage chamber 10C of each pipe part; bottoms of the two side partition walls 172 are provided with drain holes 170 at intervals; a middle cross partition wall 181 is further arranged at a longitudinal middle part in the water supply and drainage chamber 10C of each pipe part 10, and an end cross partition wall 182 is arranged at each of two ends of the water supply and drainage chamber 10C of each pipe part 10, so that the water supply and drainage chamber 10C of each pipe part 10 is partitioned into four middle compartments and four side compartments; an overflow passage 180 is arranged at the top of each of the middle cross partition wall 181 and the two end cross partition walls 182; a plurality of low cross partition walls having the height of 0.5m are further arranged at intervals at a bottom in the water supply and drainage chamber 10C of each pipe part 10;

[0056] The drain device includes a group of drain pipes 191 and a group of submersible pumps 192; the drain pipes 191 are longitudinally arranged at upper parts of both sides of the middle partition wall 171, and starting points of the drain pipes 191 are at the longitudinal middle part of each pipe part 10; the submersible pumps 192 are at bottoms of the middle compartments corresponding to the starting points of the drain pipes 191, and the submersible pumps 192 are connected to the group of drain pipes 191 through water outlet hoses in one-to-one correspondence;

[0057] The water supply device includes a group of water supply pipes 193 respectively longitudinally arranged at upper parts of outer sides of the two side partition walls 172;

[0058] The water level monitor 19 is arranged on one side of the middle partition wall 171;

[0059] Each of two sides of a top surface of the lower partition 1B is longitudinally provided with an open drain 173; each open drain 173 is provided with a grid cover plate, and the bottom of each open drain 173 is provided with ground drains at intervals of 5m and corresponding to the drain holes 170 on the side partition wall 172; a water sink 174 connecting the ground drain with the drain hole 170 is arranged on the inner side of each of two side walls of the water supply and drainage chamber 10C of the pipe part, and the height of the side wall of water sink 174 is 0.2 m;

[0060] The buoyancy-to-weight ratio adjustment devices in the shore connecting structures are arranged in a pushing side pump house 29 of the pushing side shore connecting structure and a receiving side pump house of the receiving side structure;

[0061] The pushing side pump house 29 is transversely arranged on a side of the connecting section 26 of the pushing side shore connecting structure 2, and the pushing side pump house 29 is communicated with the water supply and drainage chamber 10C of the last shore connecting pipe part 10' consolidated in the pushing side shore connecting structure 2 through a water delivery corridor 295; the receiving side pump house (not shown in the figures) is transversely arranged on one side of the pipe part consolidation section 26' of the receiving side shore connecting structure 2', and the receiving side pump house is communicated with the water supply and drainage chamber of the first pipe part through a water delivery corridor;

[0062] The top of the water delivery corridor 295 has the same height as the top of the water supply and drainage chamber 10C, and the bottom of the water delivery corridor 29A is 1m lower than the bottom of the water supply and drainage chamber 10C; an automatic control valve 296 is arranged at each of outlet ends of the two drain pipes 191 and an inlet end of the water supply pipe 193 in the water supply and drainage chamber 10C connected with a starting point of the water delivery corridor 295, and an automatic control gate 297 is arranged at an outlet end of the pump house 29 connected with an end point of the water delivery corridor 295; the water delivery corridor 295 at an outlet of the water supply and drainage chamber 10C is connected to an inlet end of the pushing side pump house 29 in a horizontal semicircle shape, and the radius of the semicircle is the maximum width of

the water supply and drainage chamber 10C; the pushing side pump house 29 is divided into a water storage chamber 291, a water delivery corridor chamber 292, a water supply valve chamber 293 and a power and monitoring chamber 294 from bottom to top;

[0063] The maximum water storage capacity of the water storage chamber 291 is the water capacity of the water supply and drainage chambers 10C of two pipe parts, and a water gauge for metering is arranged on a wall of the water storage chamber 291; tail ends of the two drain pipes 191 in the water supply and drainage chamber 10C are connected to the water storage chamber 291; a water supply pump 211, a drain pump 212, an external drain pipe 213, and an external water supply pipe 214 are arranged in the water storage chamber 291; the water supply pump 211 is connected to a tail end of the water supply pipe 193 in the water supply and drainage chamber 10C; the drain pump 212 is connected to the external drain pipe 213 for draining excessive water to the outside of the water storage chamber 291; the external water supply pipe 214 is used to supply water to the water storage chamber 21;

[0064] The water delivery corridor chamber 292 is as high as the water delivery corridor 295;

[0065] The height of the water supply valve chamber 293 is not less than 2.0 m, and a water supply valve and a water meter are arranged in the water supply valve chamber 293;

[0066] The height of the power and monitoring chamber 294 is not less than 2.8 m, and a power motor and computer monitoring equipment 298 are arranged in the power and monitoring chamber 294.

[0067] The buoyancy-to-weight ratio adjustment system of the present invention is a support system for maintaining the floating depth and stability of the floating tunnel. When the buoyancy-to-weight ratio of the submerged floating tunnel 1 is approximately 1, the gravity balance and substantially fixed floating depth of the submerged floating tunnel 1 during construction can be ensured; the change in gravity of the tunnel, caused by the generation of attachments in the sea and the like, is balanced by the automatic buoyancy-to-weight ratio adjustment system during the operation period. The buoyancy-to-weight ratio is an important control parameter for the submerged floating tunnel. The submerged cable-stayed floating tunnel of the present invention is designed in such a way that the buoyancy of the tunnel is less than own gravity of the tunnel (i.e., the buoyancy-to-weight ratio is less than 1). The reference value of the buoyancy-to-weight ratio of the floating tunnel according to the present invention without the calculation vehicle load and other use loads is 0.75 to 0.95. The buoyancy-to-weight ratio is theoretically selected according to the vibration amplitude and frequency of the tunnel caused by water flow and waves, and generally selected according to the flow rate of the water flow for intuitiveness and convenience. Smaller the flow rate of the water flow is, larger the buoyancy-to-weight ratio is. The buoyancy-to-weight ratio adjustment device is arranged in each pipe part of the submerged floating tunnel to control the actual buoyancy-to-weight ratio of the tunnel so as to meet the requirements of stability during the construction period and comfort during the operation period.

[0068] The anti-collision warning system includes a warning buoy device and a submerged warning anchor cable device; wherein

[0069] The warning buoy device includes a plurality of buoys 71, a plurality of fixed cables 72 and a plurality of warning lights 73; a plurality of buoys 71 are arranged on the water surface above the submerged floating tunnel 1 at intervals along an axis of the submerged floating tunnel 1; a plurality of fixed cables 72 are fixed between a plurality of buoys 71 and the submerged floating tunnel 1 in one-to-one correspondence; a plurality of warning lights 73 are attached to tops of a plurality of buoys 71 in one-to-one correspondence;

[0070] The submerged warning anchor cable device includes two submerged warning cables 81, a plurality of slings 82 and a plurality of warning light strips; the two submerged warning cables 81 are arranged in parallel on both sides of the submerged floating tunnel 1; pushing side shore ends of the two submerged warning cables 81 respectively penetrate through the two groups of cable steering piers 5 arranged on the pushing side shore, then extend to the ground along the cable ramps 50, and then are anchored to the two cable anchor piers 40 arranged on the pushing side shore; receiving side shore ends of the two submerged warning cables 81 respectively penetrate through the two groups of cable steering piers 5 arranged on the receiving side shore, then extend to the ground along the cable ramps 50, and then are anchored to the two cable anchor piers 40 arranged on the receiving side shore; a plurality of slings 82 are hung on the two submerged warning cables 81 at intervals; a plurality of warning light strips are mounted on a plurality of slings 82 in one-to-one correspondence.

[0071] The anti-collision warning system of the present invention can warn not only navigable objects on the water surface but also submersibles in the water, and can effectively reduce the risk that the floating tunnel is hit.

[0072] The escape system includes an automatic alarm system, an escape time extension system, and escape routes.

[0073] The automatic alarm system includes a video monitoring device, water level monitoring devices, a temperature measurement and control device, a toxic gas detection device and centralized control centers; wherein the video monitoring device, the temperature measurement and control device and the toxic gas detection device are all arranged at the top of the tunnel upper layer 10A; the water level monitoring devices are arranged in the water supply and drainage chamber 10C of each pipe part 10, the water delivery corridor 295 of the pushing side shore connecting structure 2, the pushing side pump house 29, the water delivery corridor of the receiving side shore connecting structure 2', and the receiving side

pump house; the centralized control centers are arranged in the pushing side shore connecting structure 2 and the receiving side shore connecting structure 2'. The video monitoring device includes a plurality of monitoring cameras arranged throughout the tunnel, and one monitoring camera is arranged every 10m to 20m; all the monitoring cameras are connected to a computer terminal in the centralized control center through lines, and a display screen of the computer terminal is provided with water leakage, smoke and toxic gas windows, and can give audio warnings. The water level monitoring device includes a plurality of water level monitors 19 arranged in the water supply and drainage chambers 10C of a plurality of pipe parts 10 in one-to-one correspondence, all the water level monitors 19 are connected to a water level monitoring terminal in the centralized control center by wires, and the water level monitoring terminal gives voice warning according to the increase of the water level; the water level monitoring terminal is set with an early warning value, an alarm value, a warning value, an emergency value, a limit value and an over-limit value in order from low to high, and issues a warning monitors lagging to video monitor.

[0074] The escape time extension system includes a buoyancy-to-weight ratio adjustment system, contact passage sealing doors and tunnel portal emergency sealing doors; wherein the contact passage sealing doors 60A are arranged at both ends of a contact passage 60 of the double-pipe tunnel, and the contact passage sealing doors 60A are automatic opening and closing doors; the tunnel portal emergency sealing doors are arranged at a tunnel exit of the pushing side shore connecting structure 2 and a tunnel exit of the receiving side shore connecting structure 2', and the opening and closing of the tunnel portal emergency sealing doors are controlled by the centralized control center.

[0075] The escape routes include an escape route in the tunnel and an escape route at the top of the tunnel; wherein

The escape route in the tunnel includes a tunnel pavement escape passage and a tunnel upper layer escape passage leading to the pushing side shore connecting structure 2 and the receiving side shore connecting structure 2', and the contact passage 60 of the double-pipe tunnel; the tunnel pavement escape passage is arranged in the tunnel middle layer 10B; the tunnel upper layer escape passage is arranged at the tunnel upper layer 10A and is entered through a plurality of manholes 61 formed in the upper partition 10; one of a plurality of manholes 61 is arranged every 250m to 300m on two sides of the upper partition 10 along the length of the tunnel, the size of each manhole 61 is 800mm×600mm, each manhole 61 is provided with an automatic flip door downward, and an attached ladder 62 is arranged on the automatic flip door.

[0076] The escape route at the top of the tunnel includes a plurality of spare emergency escape exits arranged and rescue submarines 64at the top of the tunnel; one of a plurality of spare emergency exits is arranged every 1 km on the top wall of the tunnel along the length of the tunnel, and an emergency hatch door 63 is arranged on each spare emergency escape exit; the rescue submarine 64 is docked at the top of the emergency hatch door 63, the bottom of the rescue submarine 64 is provided with a spare emergency hatch connected with the emergency hatch door 63, and when the spare emergency hatch is opened, a person enters the rescue submarine 64 through the ladder 65 lowered down from the spare emergency hatch.

[0077] The escape system of the present invention makes the best use of the structural layout and equipment arrangement of the pavement structure, the contact passage, the tunnel upper layer structure and the buoyancy-to-weight ratio adjustment system of the floating tunnel, to achieve reasonable utilization of resources, so that the rationality of design of the tunnel structure is increased; for the double-pipe tunnel, the contact passage is also used as an escape passage; the escape system also makes the best use of the buoyancy-to-weight ratio adjustment system, so that general leakage of the tunnel can be effectively handled without personnel evacuation; and the evacuation time is also greatly increased in the case that the tunnel is seriously destroyed and personnel evacuation is required.

[0078] The cable-stayed floating tunnel structure of the present invention adopts a linear arrangement in both the plane direction and the longitudinal direction, includes a submerged floating tunnel, a shore connecting structure, stay cables, cable anchor piers, etc. The submerged floating tunnel is usually buried deep, and is connected to a ground road through a land slope tunnel.

[0079] The shore connecting structure of the present invention is located on a stable foundation near the shore slope, and achieves the functions of connection and switching between the submerged floating tunnel and the land slope tunnel. In order to ensure the stability of the shore connecting structure and the shore slope, the original submerged slope on the waterfront side of the shore connecting structure needs to be protected and reinforced. The submerged floating tunnel is connected with the tunnel pipe part in the shore connecting structure in the form of rigid connection. Because the submerged floating tunnel is buried deep, the shore connecting structure is also required to be deep. The lower part of the shore connecting structure is used to arrange the tunnel structure and tunnel auxiliary facilities, and the upper part of the shore connecting structure can be used for other purposes such as a parking lot.

[0080] Taking into consideration of the safety risks during the operation period of the tunnel, when the trench flow is a two-way flow (tide rises and falls), and the flow velocity is very small, a two-way single cable plane tunnel is used; when the trench flow is a two-way flow (tide rises and falls), and the flow velocity is relatively large, a two-way double cable plane tunnel is used.

[0081] There are three main construction technologies

for the submerged floating tunnel of the present invention: a section-by-section submerged splicing method, a water integral splicing method and a submerged pushing method. The technology is selected by the analysis of the influence of meteorological and hydrological conditions in the sea at the tunnel site on the construction, and the analysis of the technological difficulties, etc.

[0082] Section-by-section submerged splicing method: prefabricated pipe parts are floated to mounting points one by one, submerged, connected and fastened underwater one by one. Water integral splicing method: prefabricated pipe parts are floated to temporary dock sides on the shores near the tunnel site one by one, connected and fastened in groups, then the connected groups are shifted and connected into a whole, and the whole pipe parts are turned, dragged to the water surface above the tunnel, submerged as a whole, and connected to the shores. Submerged pushing method: prefabricated pipe parts are pushed from the pushing side shore connecting structure into the receiving side shore connecting structure one by one. The first two methods are greatly affected by the meteorological and hydrological conditions in the sea at the tunnel site, and require suitable construction window periods, so the effective operation time is short, and the connection is extremely difficult; and the pushing method is nearly not affected by the meteorological and hydrological conditions, achieves connection by dry construction, but is very difficult in thrusting and water stop. After comprehensive consideration, the pushing technology is recommended.

[0083] The length of each pipe part depends on the used construction technology of the submerged floating tunnel, the lifting capacity of pipe part mounting equipment and dynamic positioning capability thereof, site conditions, engineering costs, etc. For the section-by-section submerged splicing method and the water integral splicing method, the length of each pipe part is preferably 120m to 180m; and for the submerged pushing method, the length of each pipe part ispreferably60 to100 m.

[0084] The submerged cable-stayed floating tunnel structure of the present invention is suitable for any water area with a seismic intensity of not more than a magnitude of 7 and a stable shore slope, and is particularly suitable for a water area where the flow velocity is small. Smaller the flow velocity is, more stable more comfortable and safer the tunnel is, during the operation. For the water areas having depths of more than 60m and widths of more than 1500m, it is more suitable than bridges and immersed tube tunnels. For shore slopes in soft soil geological layers or new artificial islands, the foundation must be reinforced to ensure the stability of the slope. For areas with seismic intensities of more than a magnitude of7, safety and human psychology should be considered for careful use of the cable-stayed floating tunnel structure of the present invention. The cable-stayed floating tunnel structure of the present invention is not suitable for areas with ground fissures, seismic zones, and geological plate junction areas. Due to the limitation of the stay cable angle, the water span of the cable-stayed floating tunnel structure of the present invention should not be more than 4 km.

[0085] The above embodiments are only used to illustrate the present invention, but not to limit the present invention. Those skilled in related technical fields may also make various transformations or variations without departing from the spirit and scope of the present invention. Therefore, all equivalent technical solution shall also fall within the scope of the present invention, and shall be defined by the claims.

Claims

1. A submerged cable-stayed floating tunnel structure, comprising a tunnel body, shore connecting structures, a cable anchor system, a buoyancy-to-weight ratio adjustment system, an anti-collision warning system and an escape system; the shore connecting structures comprise a pushing side shore connecting structure arranged on a pushing side shore and a receiving side shore connecting structure arranged on a receiving side shore in one-to-one correspondence; the tunnel body comprises a submerged floating tunnel, a pushing side land slope tunnel and a receiving side land slope tunnel; a waterfront end of the pushing side land slope tunnel and a waterfront end of the receiving side land slope tunnel are connected to a backwater end of the pushing side shore connecting structure and a backwater end of the receiving side shore connecting structure in one-to-one correspondence; the submerged floating tunnel is formed by connecting a plurality of pipe parts, and each pipe part is partitioned into a tunnel upper layer, a tunnel middle layer and a tunnel lower layer by an upper partition and a lower partition, the space of the tunnel upper layer being a process chamber; the tunnel middle layer is a tunnel traffic chamber; the tunnel lower layer is a water supply and drainage chamber; wherein,
the pushing side shore connecting structure sequentially comprises from the sea to the land: a scour protection section, a starting section, a portal section retaining wall, a portal section, a waterfront side wall, a thrust section, a sealing section, a connecting section, a pushing section, a horizontal transportation section and a backwater side wall; the connecting section and the pushing section are arranged in a pipe part connecting box that can be opened and closed; the receiving side shore connecting structure sequentially comprises from the sea to the land: a submerged revetment section, a receiving section, a portal section retaining wall, a portal section, a waterfront side wall, a pipe segment stabilizing section, a sealing section, a pipe fixing section, a drawing and anchor section and a backwater side wall;
a plurality of pipe segments of the submerged float-

ing tunnel are connected by pipe joints, joint fasteners, filling materials, and water stop; a tail of the last pipe part and a head of the first pipe part are located in the pushing side shore connecting structure and the receiving side shore connecting structure in one-to-one correspondence, and an outer surface of the tail of the last pipe part is consolidated with an inner surface of the pipe part connecting box in the pushing side shore connecting structure by pouring concrete; an outer surface of the head of the first pipe part is consolidated with an inner surface of the pipe part consolidation section in the receiving side shore connecting structure by pouring concrete;

the cable anchor system employs a two-way single cable plane or a two-way double cable plane and comprises four cable receiving wells, four groups of cable steering piers, cable ramps, and multiple strands of stay cables; the four cable receiving shafts are respectively arranged on the pushing side shores on both sides of the tunnel and receiving side shores on both sides of the tunnel; each cable receiving well comprises a cable anchor pier and a monitoring room; the four groups of cable steering piers are respectively arranged on pushing side shore slopes and receiving side shore slopes on both sides of the tunnel and are close to the four cable receiving shafts in one-to-one correspondence; the cable ramp is arranged on the shore slope between each group of cable steering piers and the corresponding cable receiving shaft; one end of the multiple strands of stay cables is anchored at intervals on both sides of the submerged floating tunnel, and the other end of each of the multiple strands of stay cables passes through steering cable guides in the cable steering piers, then extends to the ground along the submerged cable ramps, and is anchored to cable anchor piers;

the buoyancy-to-weight ratio adjustment system comprises a buoyancy-to-weight ratio adjustment device in the tunnel pipe part and buoyancy-to-weight ratio adjustment devices in the shore connecting structures; the buoyancy-to-weight ratio adjustment device in the tunnel pipe part is arranged in the water supply and drainage chamber of each pipe part and comprises a drain device, a water supply device and a water level monitor arranged in the water supply and drainage chamber of each pipe part; the buoyancy-to-weight ratio adjustment devices in the shore connecting structures are arranged in a pushing side pumping room of the pushing side shore connecting structure and a receiving side pump house of the receiving side structure; the pushing side pump house is transversely arranged on a side of the connecting section of the pushing side shore connecting structure, and the pushing side pump house is communicated with the water supply and drainage chamber of the last pipe part through a water delivery corridor; the receiving side pump house is transversely arranged on a side of the pipe part consolidation section of the receiving side shore connecting structure, and the receiving side pump house is communicated with the water supply and drainage chamber of the first pipe part through a water delivery corridor;

each of the pushing side water pump room and the receiving side water pump room is divided into a water storage chamber, a water delivery corridor chamber, a water supply valve chamber and a power and monitoring chamber from bottom to top;

the anti-collision warning system comprises a warning buoy device and a submerged warning anchor cable device; and

the escape system comprises an automatic alarm system, an escape time extension system, and escape routes.

2. The submerged cable-stayed floating tunnel structure according to claim 1, wherein the cross-sectional structure of the submerged floating tunnel is round or prismatic, and the angle of the prismatic tip is less than or equal to 60°.

3. The submerged cable-stayed floating tunnel structure according to claim 1, wherein

the submerged revetment section of the pushing side shore connecting structure is on a submerged slope on a waterfront side of the shore connecting structure, and rip-raps are provided on the surface of the slope to prevent scouring;

the starting section of the pushing side shore connecting structure is a horizontal section between the portal section retaining wall and a slope top line of the submerged revetment section, and the design elevation of the starting section is a design bottom elevation of a cross section of the submerged floating tunnel to form a pending surface on both shores of the submerged floating tunnel;

the portal section of the pushing side shore connecting structure is arranged between the portal section retaining wall and the waterfront side wall; the portal section of the pushing side shore connecting structure is further provided with a temporary sealing door and a corresponding water stop device both on the front side of the waterfront side wall; the temporary sealing door is provided with a water blocking plug;

the thrust section of the pushing side shore connecting structure is on the rear side of the waterfront side wall and is of a sealed box structure, the top of the thrust section is provided with a manhole and an embedded cover plate, and a hoop type thrust device is arranged in the thrust section;

the sealing section of the pushing side shore connecting structure is behind the thrust section, the sealing section is a sealing wall with a wall hole, front and rear sides of the sealing wall are respectively provided with a sealing hoop along the circumference of the wall hole, and a water stop strip is ar-

ranged between the wall hole and the outer surface of the pipe part;
the connecting section of the pushing side shore connecting structure is behind the sealing section, i.e., at a position which is left and exposed behind the sealing section after the pipe part is pushed forward, and is used to connect with the subsequent pipe part, and the length of the connecting section is the length of part of the pipe part which is left and exposed;
the pushing section of the pushing side shore connecting structure is behind the connecting section, and the bottom of the pushing section is provided with a carrying airbag; a rear part of the pushing section is provided with a pushing trolley in-position section, middle parts of two side walls of the pipe part connecting box are respectively provided with a corbel, the two corbels are respectively provided with a pushing trolley track, and thrust seats are arranged at pipe part connecting positions of the two corbels of the pipe part connecting box;
the horizontal transportation section of the pushing side shore connecting structure is not shorter than each pipe part, and the bottom of the horizontal transportation section is provided with a jacking beam driven by a jack;
the structures of the submerged revetment section, the receiving section, the portal section retaining wall, the portal section, the waterfront side wall, the sealing section and the backwater side wall of the receiving side shore connecting structure are the same as the structures of the submerged revetment section, the starting section, the portal section retaining wall, the portal section, the waterfront side wall, the sealing section and the backwater side wall of the pushing side shore connecting structure in one-to-one correspondence;
the waterfront side wall of the receiving side connecting structure is provided with a wall hole, and a water stop device is arranged on an upstream face of the waterfront side wall and along the wall hole;
the pipe part stabilizing section is behind the waterfront side wall, has a reinforced concrete box structure, and is provided with a hoop type stabilizing device therein;
the sealing section is behind the pipe part stabilizing section, the sealing section is a sealing wall with a wall hole, and a water stop device is also arranged on an upstream face of the sealing wall and along the wall hole;
the pipe part consolidation section is behind the sealing section, has the same structure as the pipe part stabilizing section, and is also of a reinforced concrete box structure, and a steel sealing door is arranged at the tail of the pipe part consolidation section;
the traction anchor section is between the steel sealing door of the pipe part consolidation section and the backwater side wall, a reinforced concrete abutment is arranged at the bottom of the traction anchor section, a pile foundation is arranged below the abutment, and a high-power traction device for a traction cable is arranged on the abutment.

4. The submerged cable-stayed floating tunnel structure according to claim 1, wherein
the pipe joint is a socket and spigot joint, and an outer surface of a socket and an inner surface of a spigot of each pipe part are uniformly and correspondingly provided with a plurality of countersunk joint bolt holes in the radial direction;
the joint fasteners comprise joint internal fasteners and joint external fasteners; the joint internal fasteners are high-strength stainless steel bolts, nuts and washers inserted in the joint bolt holes and are of a vertical anchoring type; the joint external fasteners comprise a plurality of anchor seats arranged on the inner surface of each pipe part and near an orifice, and steel strands or pre-stressed steel bars connected between the anchor seats of two connected pipe parts by an anchorage device;
the joint fillers comprise a joint gap filler filled between the inner surface of the socket and the outer surface of the spigot of the two connected pipe parts, and a bolt hole filler filled in the joint bolt holes of the two connected pipe parts;
the joint water stop material comprises an outer water stop ring arranged between an end face of the socket and a stop surface of the spigot of the two connected pipe parts, and an inner water stop ring arranged between an end face of the spigot and a stop surface of the socket.

5. The submerged cable-stayed floating tunnel structure according to claim 1, wherein
the cable anchor pier is arranged at a lower part of the cable receiving shaft; a waterfront side of the cable anchor pier is provided with a cable guide; a middle part of the cable anchor pier is provided with a cable force monitoring groove, a cable force monitor is arranged in the cable force monitoring groove, and an anchor block is arranged at each of two ends of the cable force monitoring groove; an electric windlass is arranged at a rear end of the cable anchor pier; the monitoring room is arranged at an upper part of the cable receiving shaft, and a stay cable monitoring device is arranged in the monitoring room;
each group of cable steering piers is located at the maximum depth of a channel; the number of each group of cable steering piers is half of the total number of the stay cables; the bottom of each cable steering pier is higher than the elevation of the submerged floating tunnel and not higher than the minimum bottom elevation of the channel; the interior of each cable steering pier is provided with a cable passage along the stay cable, and a steering cable guide

is pre-buried in the cable passage.

6. The submerged cable-stayed floating tunnel structure according to claim 1, wherein
a middle partition wall and two side partition walls are longitudinally arranged in the water supply and drainage chamber of each pipe part; bottoms of the two side partition walls are provided with drain holes at intervals; a middle cross partition wall is further arranged at a longitudinal middle part in the water supply and drainage chamber of each pipe part, and an end cross partition wall is arranged at each of two ends of the water supply and drainage chamber of each pipe part, so that the water supply and drainage chamber of each pipe part is partitioned into four middle compartments and four side compartments; an overflow passage is arranged at the top of each of the middle cross partition wall and the two end cross partition walls;
the drain device comprises a group of drain pipes and a group of submersible pumps; the drain pipes are longitudinally arranged at upper parts of both sides of the middle partition wall, and starting points of the drain pipes are at the longitudinal middle part of each pipe part; the submersible pumps are at bottoms of the middle compartments corresponding to the starting points of the drain pipes, and the submersible pumps are connected to the drain pipes through water outlet hoses in one-to-one correspondence;
the water supply device comprises a group of water supply pipes respectively longitudinally arranged at upper parts of outer sides of the two side partition walls;
the water level monitor is arranged on one side of the middle partition wall;
the maximum water storage capacity of the water storage chamber is the water capacity of the water supply and drainage chambers of two pipe parts, and a water gauge for metering is arranged on a wall of the water storage chamber; tail ends of the drain pipes in the water supply and drainage chamber are connected to the water storage chamber; a water supply pump, a drain pump, an external drain pipe, and an external water supply pipe are arranged in the water storage chamber; the water supply pump is connected to a tail end of the water supply pipe in the water supply and drainage chamber; the drain pump is connected to the external drain pipe for draining excessive water to the outside of the water storage chamber; the external water supply pipe is used to supply water to the water storage chamber;
the water delivery corridor chamber is as high as the water delivery corridor;
the height of the water supply valve chamber is not less than 2.0 m, and a water supply valve and a water meter are arranged in the water supply valve chamber;
the height of the power and monitoring chamber is not less than 2.8 m, and a power motor and computer monitoring equipment are arranged in the power and monitoring chamber.

7. The submerged cable-stayed floating tunnel structure according to claim 1, wherein
the warning buoy device comprises a plurality of buoys, a plurality of fixed cables and a plurality of warning lights; a plurality of buoys are arranged on the water surface above the submerged floating tunnel at intervals along an axis of the submerged floating tunnel; a plurality of fixed cables are fixed between a plurality of buoys and the submerged floating tunnel in one-to-one correspondence; a plurality of warning lights are attached to tops of a plurality of buoys in one-to-one correspondence;
the submerged warning anchor cable device comprises two submerged warning cables, a plurality of slings and a plurality of warning light strips; the two submerged warning cables are arranged in parallel on both sides of the submerged floating tunnel; pushing side shore ends of the two submerged warning cables respectively penetrate through the two groups of cable steering piers arranged on the pushing side shore, then extend to the ground along the cable ramps, and are anchored to the two cable anchor piers arranged on the pushing side shore, and receiving side shore ends of the two submerged warning cables respectively penetrate through the two groups of cable steering piers arranged on the receiving side shore, then extend to the ground along the cable ramps, and are anchored to the two cable anchor piers arranged on the receiving side shore; a plurality of slings are hung on the two submerged warning cables at intervals; a plurality of warning light strips are mounted on a plurality of slings in one-to-one correspondence.

8. The submerged cable-stayed floating tunnel structure according to claim 1, wherein
the automatic alarm system comprises a video monitoring device, water level monitoring devices, a temperature measurement and control device, a toxic gas detection device and centralized control centers; the video monitoring device, the temperature measurement and control device and the toxic gas detection device are all arranged at the top of the tunnel upper layer; the water level monitoring devices are arranged in the water supply and drainage chamber of each pipe part, the water delivery corridor of the pushing side shore connecting structure, the pushing side pump house, the water delivery corridor of the receiving side shore connecting structure, and the receiving side pump house; the centralized control centers are arranged in the pushing side shore connecting structure and the receiving side shore connecting structure;

the escape time extension system comprises a buoyancy-to-weight ratio adjustment system, contact passage sealing doors and tunnel portal emergency sealing doors;
the contact passage sealing doors are arranged at both ends of a contact passage of the double-pipe tunnel;
the tunnel portal emergency sealing doors are arranged at a tunnel exit of the pushing side shore connecting structure and a tunnel exit of the receiving side shore connecting structure;
the escape routes comprise an escape route in the tunnel and an escape route at the top of the tunnel; the escape route in the tunnel comprises a tunnel pavement escape passage and a tunnel upper layer escape passage leading to the pushing side shore connecting structure and the receiving side shore connecting structure, and the contact passage of the double-pipe tunnel; the tunnel pavement escape passage is arranged in the tunnel middle layer; the tunnel upper layer escape passage is arranged at the tunnel upper layer and is entered through a plurality of manholes formed in the upper partition; the escape route at the top of the tunnel comprises a plurality of spare emergency escape exits arranged and rescue submarines at the top of the tunnel; an emergency hatch door is arranged on each spare emergency escape exit; the rescue submarine is docked at the top of the emergency hatch door, and the bottom of the rescue submarine is provided with a spare emergency hatch connected with the emergency hatch door.

9. The submerged cable-stayed floating tunnel structure according to claim 1, wherein the pushing side land slope tunnel and the receiving side land slope tunnel are both provided with an open trench tunnel and a tunnel according to the mine tunneling method in sequence downwards from the ground; and the open trench tunnel is provided with an open section, a grating section and a buried section downwards from the ground.

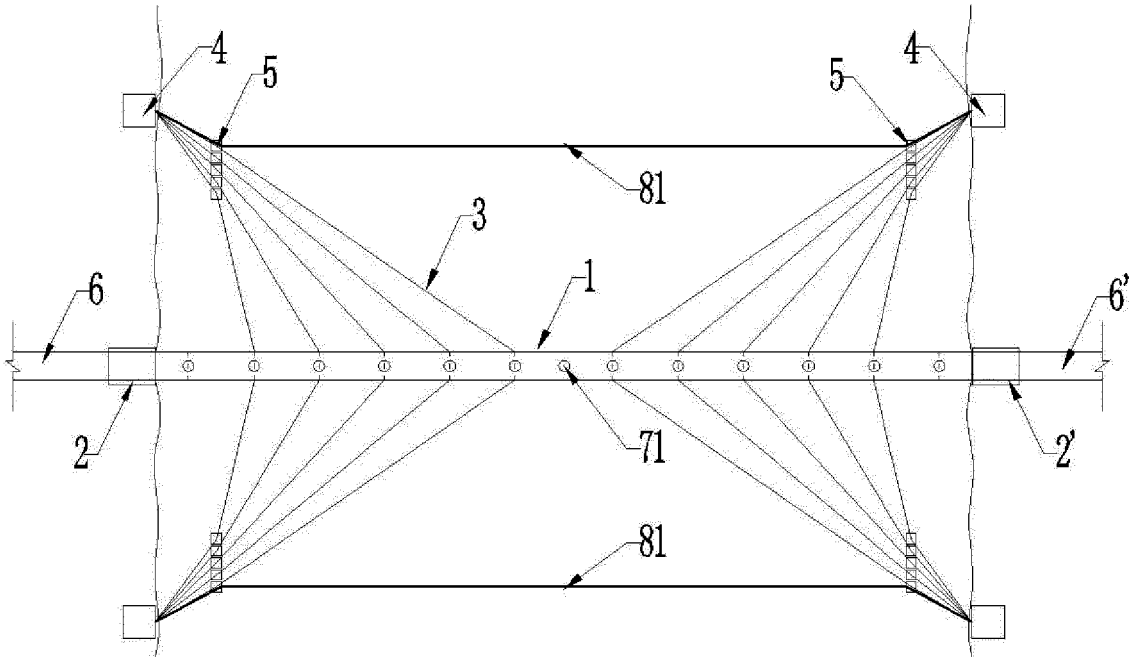

Fig. 1

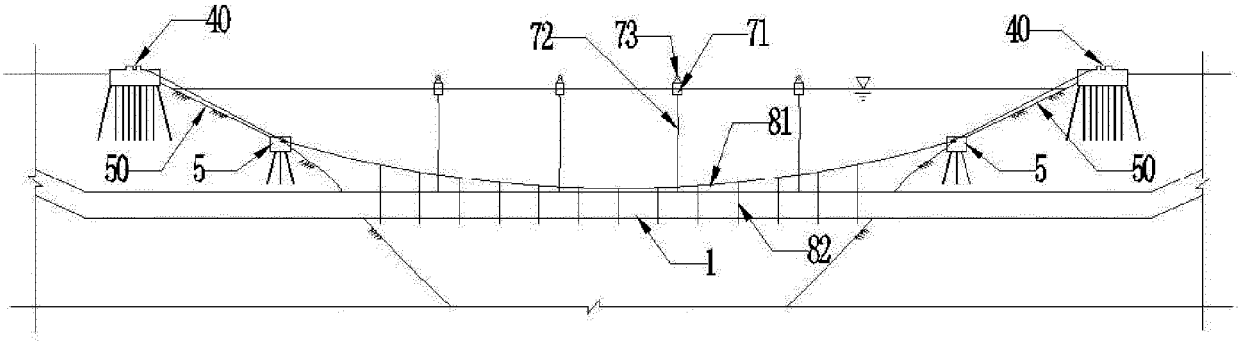

Fig. 2

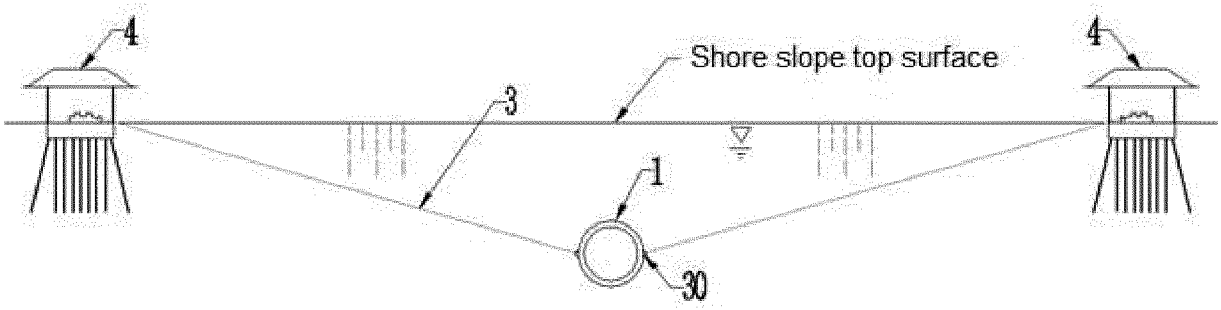

Fig. 3

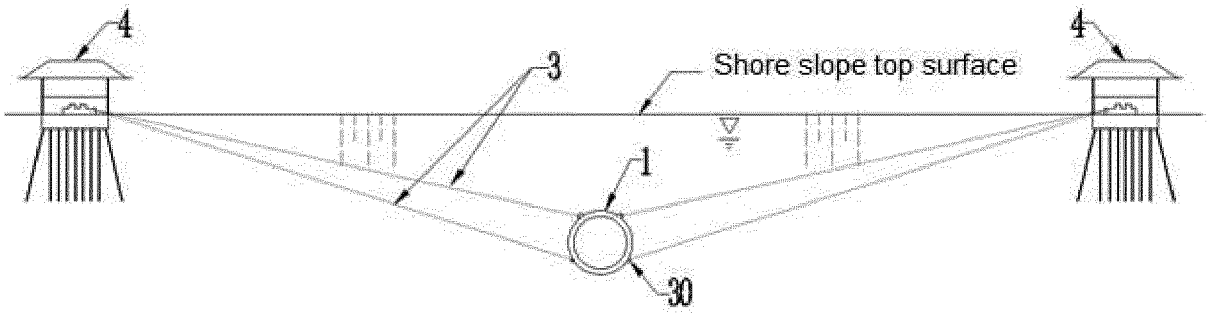

Fig. 4

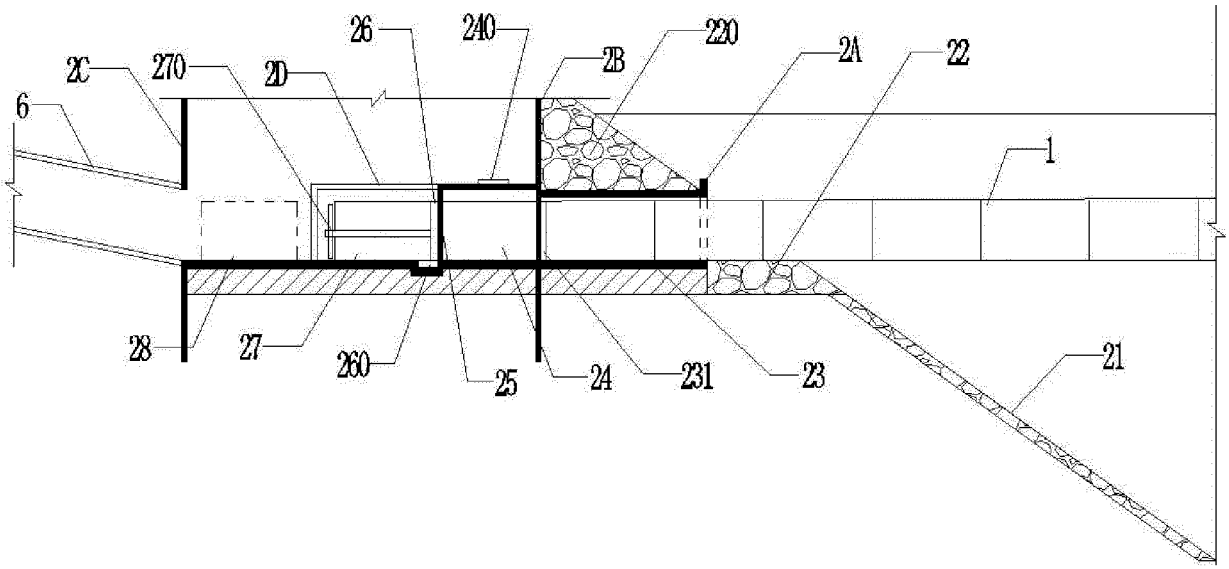

Fig. 5

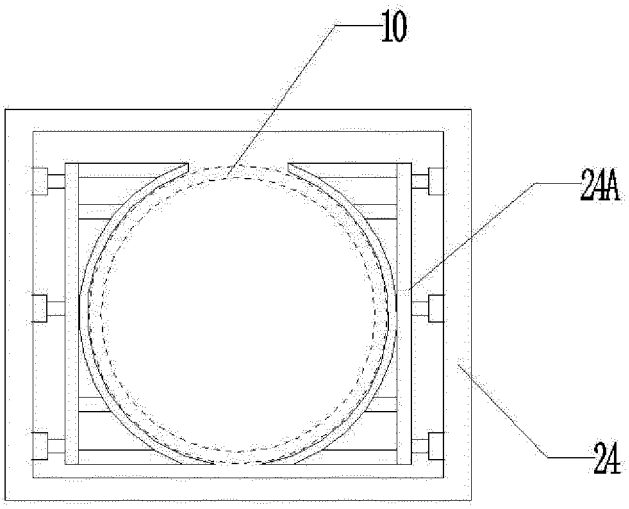

Fig. 6

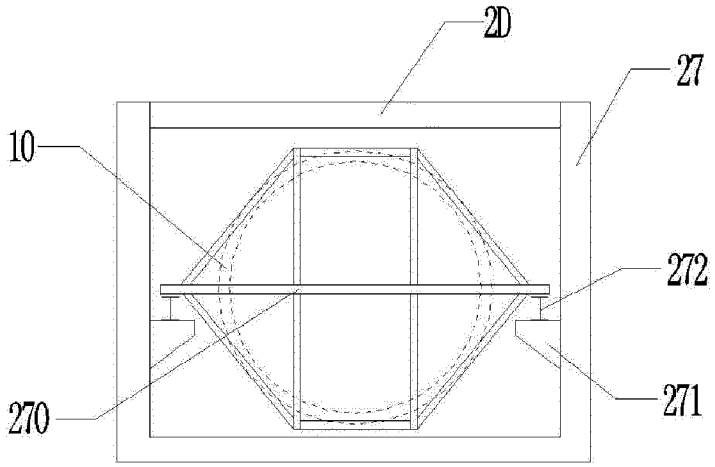

Fig. 7

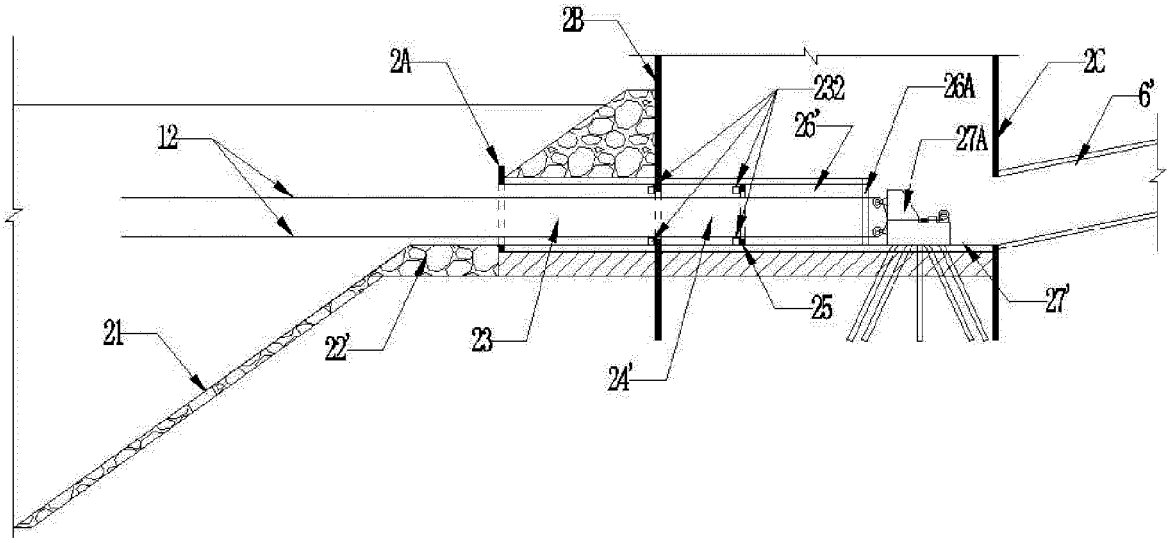

Fig. 8

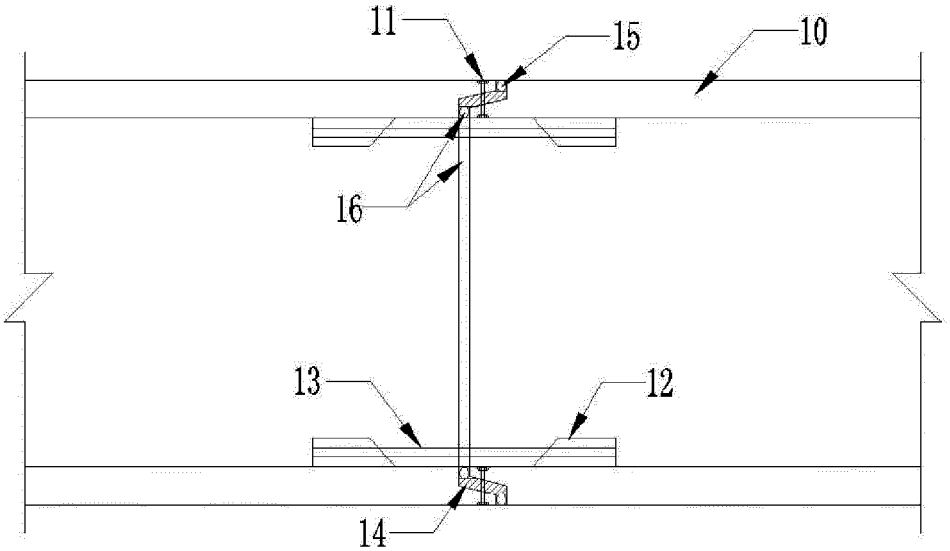

Fig. 9

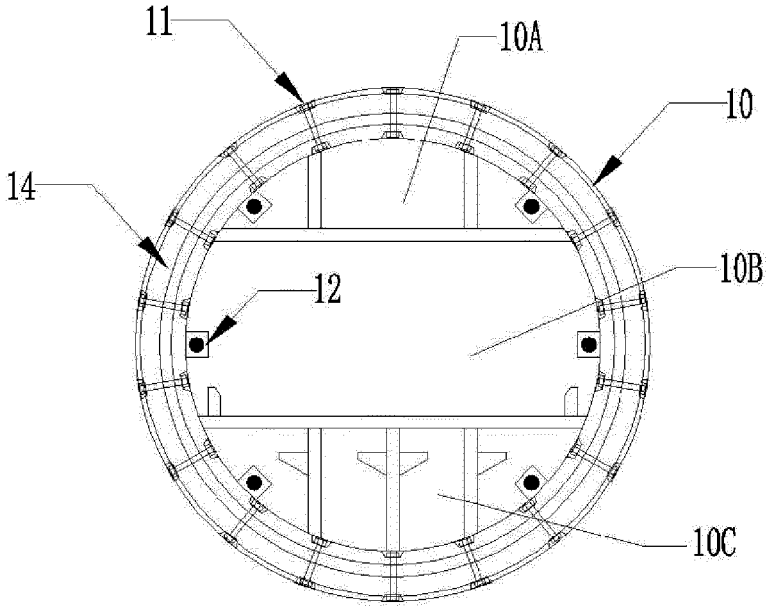

Fig. 10

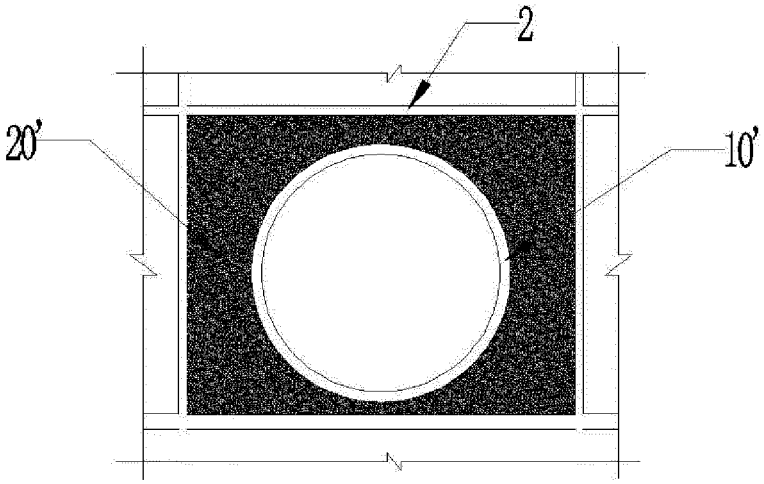

Fig. 11

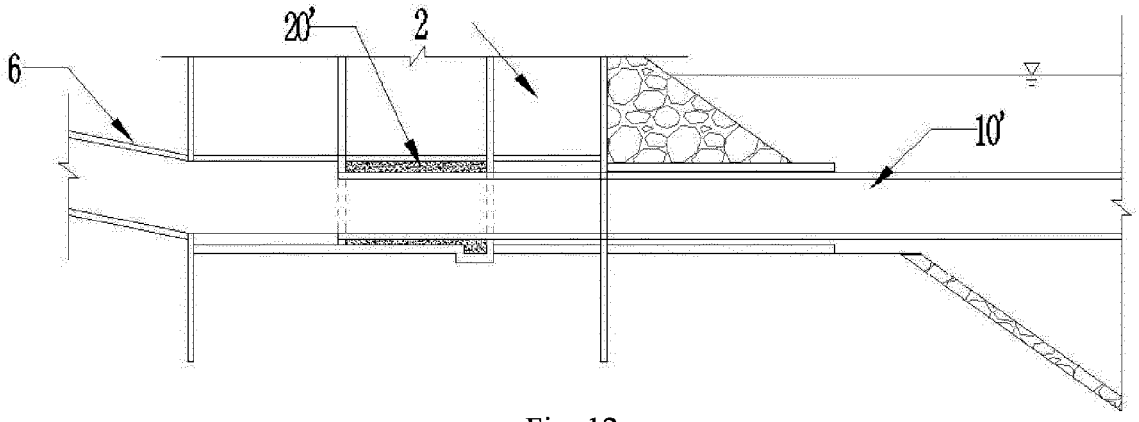

Fig. 12

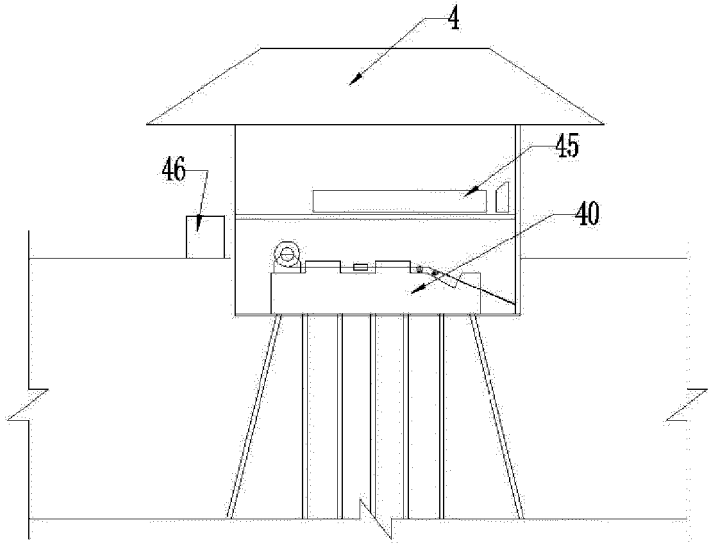

Fig. 13

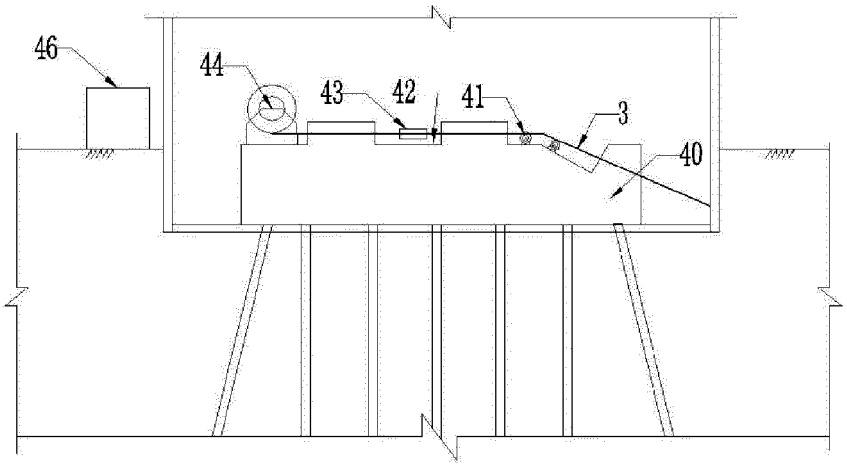

Fig. 14

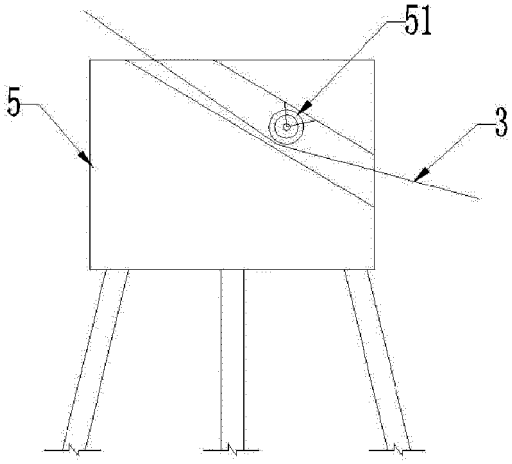

Fig. 15

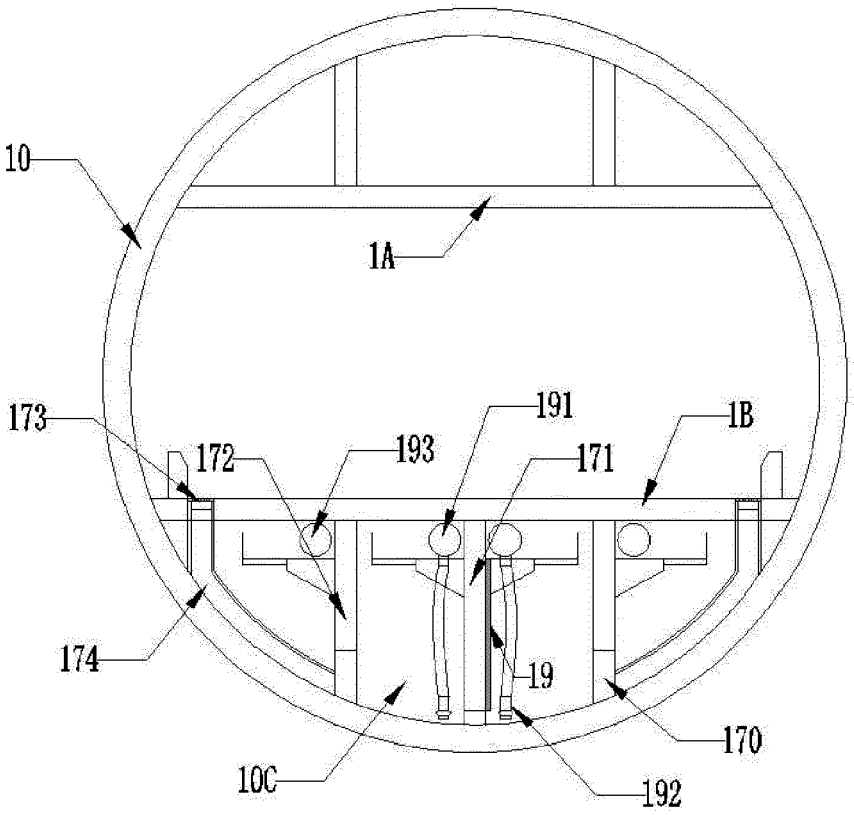
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Fig. 16

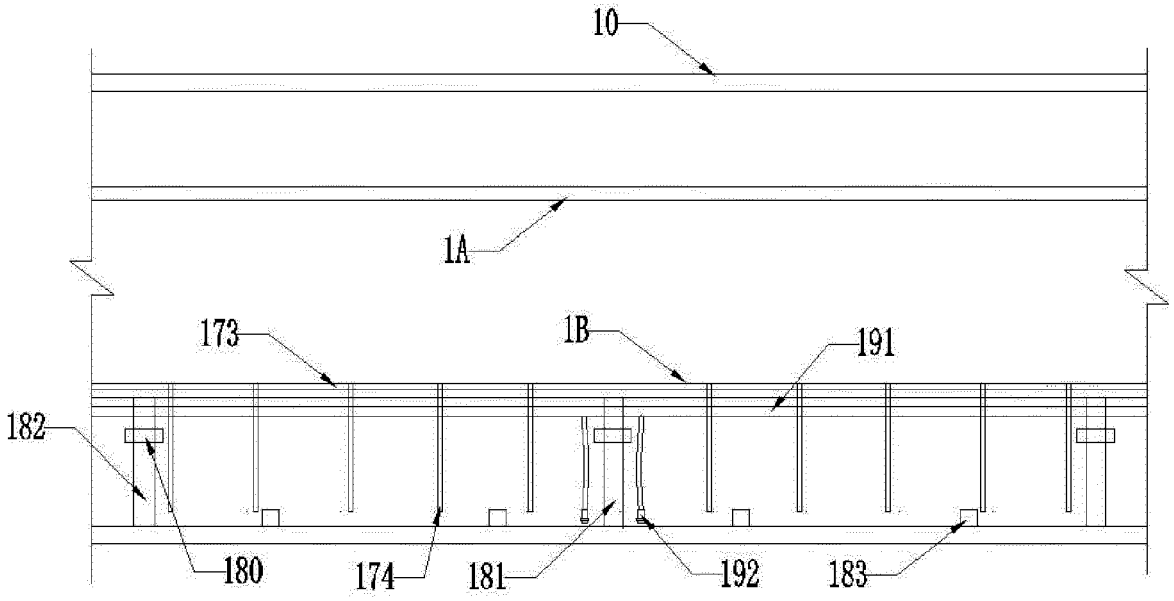
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Fig. 17

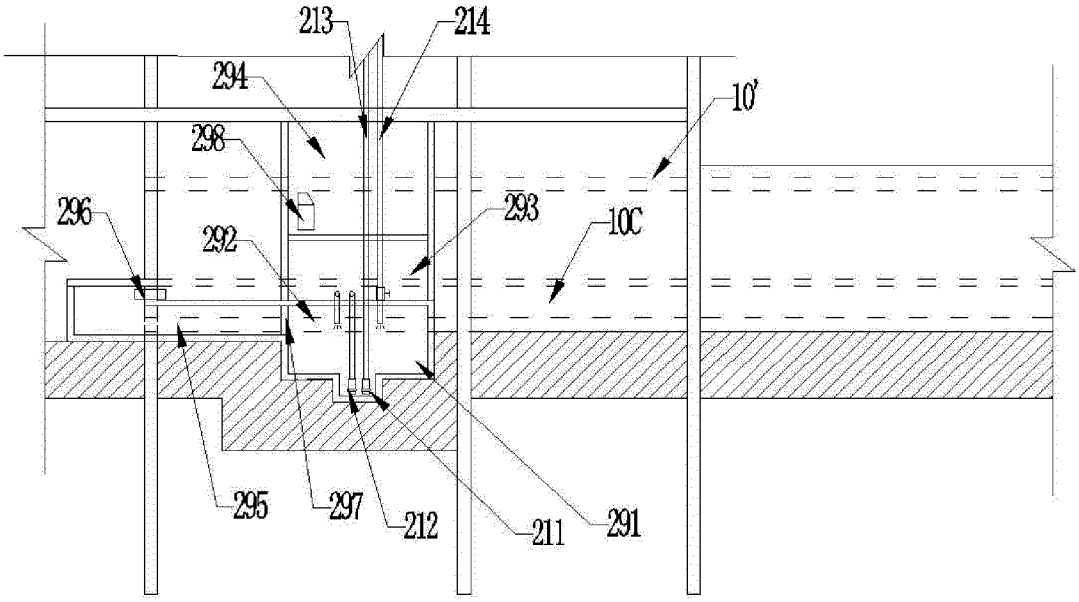

Fig. 18

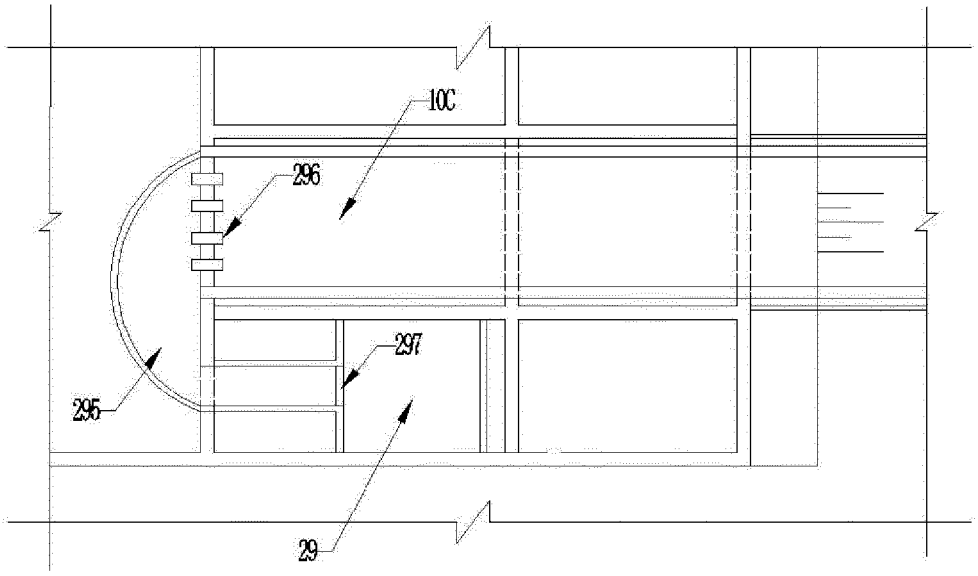

Fig. 19

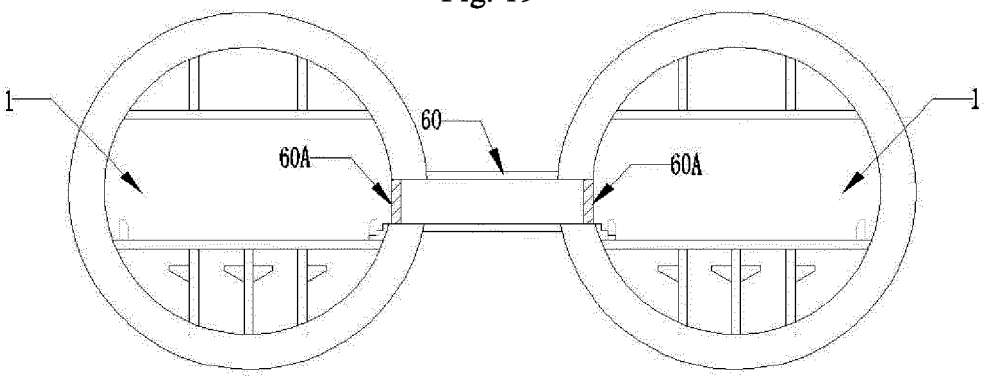

Fig. 20

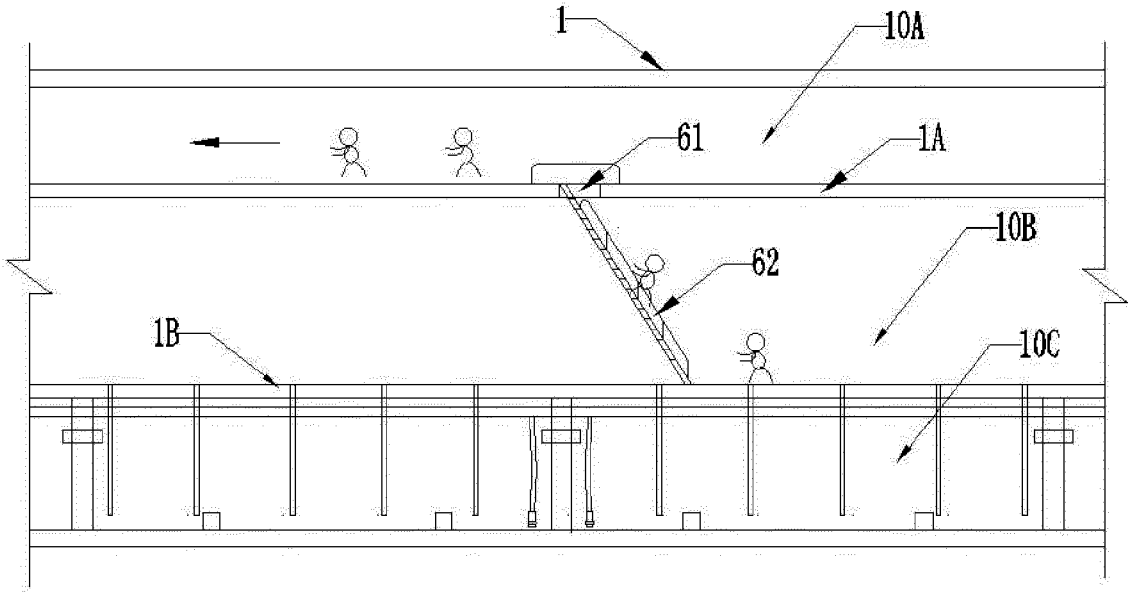

Fig. 21

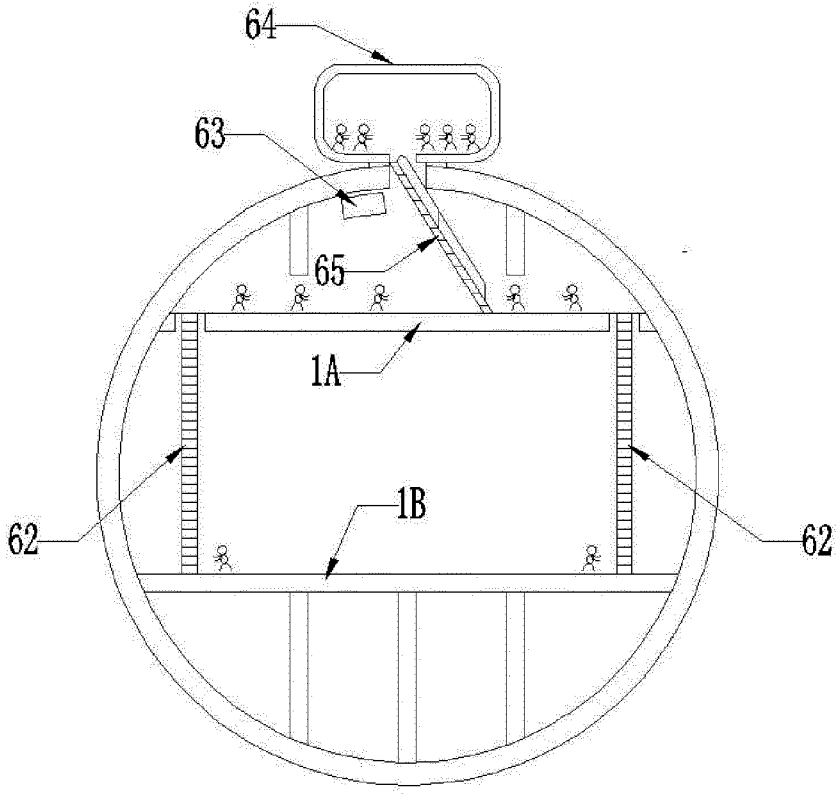

Fig. 22

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 21 15 2291

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	CN 1 590 658 A (LIU JISHENG [CN]) 9 March 2005 (2005-03-09) * the whole document *	1-9	INV. E02D29/067 E02D29/063 E02D29/07
A	GB 2 016 065 A (PRECONTRAINTE STRUCTURES SOC F) 19 September 1979 (1979-09-19) * the whole document *	1-9	
A	US 5 899 635 A (KUJA MICHAEL W [US] ET AL) 4 May 1999 (1999-05-04) * page 3, paragraph 4 - page 19, paragraph 8; figures 9-12 *	1-9	
A	CN 107 700 543 A (CCCC FIRST HARBOR ENG CO LTD ET AL.) 16 February 2018 (2018-02-16) * page 2, paragraph 3 - page 7, paragraph 5; figures 1-2 *	1-9	

TECHNICAL FIELDS SEARCHED (IPC)
E02D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	8 July 2021	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
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 21 15 2291

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
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08-07-2021

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 1590658 A	09-03-2005	NONE	
GB 2016065 A	19-09-1979	FR 2424364 A1	23-11-1979
		GB 2016065 A	19-09-1979
		IT 1165161 B	22-04-1987
		JP S54121527 A	20-09-1979
US 5899635 A	04-05-1999	US 5899635 A	04-05-1999
		US 6450734 B1	17-09-2002
CN 107700543 A	16-02-2018	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82