SPECIFICATION

TITLE: CONSTRUCTION METHOD OF UNDERGROUND STRUCTURE

## Background of the Invention

### Field of the Invention

The present invention relates to a construction method of an underground structure, capable of implementing an underground structure having a greater width in a ground under a railroad, road, or the like in a direction traversing it, without bringing about inconvenience to the upper traffic upon excavatingly advancing to construct the crossed underground structure.

### Description of the Related Art

In a field of railroad in Japan, the mainstream of a construction method of an underground structure crossed with a railroad thereon has been initially an open cut method, a temporary track method, or a method (grillage girder method) for temporarily supporting a rail track. However, it has become difficult to adopt the open cut method accompanied by numerous operations on a rail track, due to the progressively increased number of train transits. This has led to a development of a non-open cut method as a method capable of constructing a structure under a rail track in a manner to be crossed therewith and in a state ensuring transits of trains. This method is basically

configured to propel, by a jack, a precast concrete box (box culvert) having a cutting edge attached thereto, by excavating a portion of a ground at the cutting edge from an inside of the box to thereby form a space in the ground.

FIG. 16 shows a so-called jacking method configured to attach a cutting edge 2 based on a steel-made hood to a front end of a precast concrete box (box culvert) 1 in a manner to conduct excavation inside the cutting edge 2 to provide a space in front of it, and to propel the concrete box 1 by means of a propulsive jack 4 installed in a starting vertical shaft 3.

In the figure, reference numeral 9 designates an arrival vertical shaft, and the starting vertical shaft 3 and arrival vertical shaft 9 are constructed by retaining the earth by means of earth retaining members 13 in a manner to hold therebetween a traversing site under an upper traffic 8 such as a rail track.

Further, reference numerals 5, 6, and 7 in the figure designate a reaction wall provided in the starting vertical shaft 3, a strut, and a foundation concrete, respectively. It is noted that the concrete box 1 is longitudinally extended by concatenating rectangular unit boxes 1a each having a length of about 1 to 2 meters.

In this way, the concrete box 1 is propelled under the upper traffic 8 such as a rail track, in a manner to remove the cutting edge 2 upon arrival thereof at the arrival vertical shaft 9, and to utilize the buried

concrete box 1 as a tunnel or another underground structure.

Incidentally, it is required to provide a protecting work for supporting an upper traffic so as to excavatingly advance an underground structure having a greater width in a ground under a railroad, road, or the like in a direction traversing it, and, as such a protecting work, provision of a pipe roof 16 has been conventionally and exemplarily conducted which comprises steel pipes juxtaposed horizontally.

Conducted thereby is a pipe roof method configured to previously insert a pipe roof (steel pipes) 16 under a rail track as a protecting work for the rail track, in a manner to temporarily support the rail track by a false-work for each steel pipe and to subsequently excavate soil and sand under the pipe roof 16 to thereby construct a concrete box 1.

The pipe roof 16 is constructed by continuously arranging steel pipes so as to enclose, as a gate-shaped frame, the upper and lateral sides of the concrete box 1 having a rectangular cross section as shown in FIG. 17, and the concrete box 1 is caused to be inserted through the frame formed by the pipe roof 16 while leaving a spacing of a few tens of centimeters therebetween.

## Summary of the Invention

In this way, the jacking method shown in FIG. 16 is configured to propel the concrete box 1 by the propulsive

jack 4 installed in the starting vertical shaft 3, such that the concrete box 1 is subjected to a frictional resistance from the ground which resistance is increased as the laid length of the concrete box 1 is extended, in a manner to require a correspondingly enhanced propulsion, thereby increasing the size of the propulsive jack.

It is therefore an object of the present invention to provide a construction method capable of constructing a structure in a ground by towing the structure made of a full-size precast concrete to thereby eliminate the inconvenience in case of the above-described conventional example, which construction method is extremely high in safety, which construction method never requires large-scale facilities unlike a shield tunneling method, and which construction method never leaves a traversing site in an unstable state over a long period of time unlike an open cut method configured to form a large ditch in a ground while conducting an earth retainment in a manner to form a concrete structure by a mold in the ditch, and unlike a cast-in-place concrete method based on a temporary support by a false-work, configured to construct the false-work and excavate a ground therein to thereby form a concrete structure.

Particularly, it is an object of the present invention to provide a construction method of an underground structure, which construction method is capable of pushing forward, by a smaller force, a precast concrete

box (box culvert) to be buried, by attaching a cutting edge to a front end of the precast concrete box to conduct excavation of a ground at a face of the cutting edge, and by towing the box (box culvert) in the ground by means of a PC wire penetrated through a traversing portion and a specialized towing jack.

To achieve the above object, the scope of the invention recited in Claim 1 resides in a construction method of an underground structure, comprising the steps of:

installing precast concrete boxes each having a cutting edge based on a steel-made hood attached to a front end of the concrete box, at both sides of a traversing site, respectively, such that towing directions of the precast concrete boxes are opposed to each other;

attaching a towing jack to a rear portion of one of the precast concrete boxes, attaching a fixing member to a rear portion of the other, and penetrating a PC wire as a towing member through the traversing portion in a manner to fix ends of the PC wire to the towing jack and the fixing member, respectively; and

using the towing jack to mutually tow the precast concrete boxes in a box-by-box manner utilizing the cooperating one of the precast concrete boxes as a reactive resistance body.

The scope of the invention recited in Claim 2 resides in a construction method of an underground structure,

comprising the steps of:

installing a reactive body at a side of an arrival vertical shaft, and installing a precast concrete box having a rear portion provided with a towing jack at a side of a starting vertical shaft;

penetrating a PC wire as a towing member through a traversing portion, and fixing ends of the PC wire to the towing jack and a fixing member provided on the reactive body; and

using the towing jack to tow the precast concrete box from the side of the starting vertical shaft toward the side of the arrival vertical shaft by the PC wire, by using the reactive body as an anchor.

The scope of the invention recited in Claim 3 resides in the construction method of an underground structure, further comprising the steps of:

dividing the concrete box into multiple concrete boxes, and locating intermediate pushing jacks between adjacent two concrete boxes, respectively; and

operating the applicable intermediate pushing jack to excavatingly advance the concrete box forward of the applicable intermediate pushing jack in a box-by-box manner, and finally making the intermediate pushing jacks free and advancing the rearmost concrete box by the towing jack.

The scope of the invention recited in Claim 4 resides in a construction method of an underground structure, comprising the steps of:

arranging multiple precast concrete boxes in a row in the longitudinal direction while providing intermediate pushing jacks between adjacent two precast concrete boxes, respectively, in a manner to attach a cutting edge to the foremost concrete box, to attach a towing jack to a rear portion of the rearmost concrete box, to attach a fixing member at a front portion of the foremost concrete box, and to mutually couple the towing jack and fixing member by a PC wire through the arranged multiple concrete boxes;

advancing all the concrete boxes by constant distances, respectively, in a manner that a portion of a ground at the cutting edge is excavated from an inside of the cutting edge such that the applicable concrete box is advanced by a constant distance by extending a stroke of the intermediate pushing jack interposed between the applicable concrete box and the following concrete box, sequentially from the foremost concrete box to the rearmost concrete box, and upon completion of the advancement of all the concrete boxes by the constant distances, respectively, the same operation as the above is repeated from the foremost concrete box to the rearmost concrete box; and

conducting the above steps in such a manner that, for propulsion of an applicable concrete box closer to the rearmost concrete box, self-weights of the concrete boxes subsequent to the applicable concrete box are insufficient, so that this insufficient weight is supplemented by transmitting a jack reactive force to those concrete boxes

forward of the applicable concrete box by the PC wire, and for propulsion of the rearmost concrete box, the towing jack is operated to tense up the PC wire, thereby pulling the rearmost concrete box forwardly to advance it.

The scope of the invention recited in Claim 5 resides in the construction method of an underground structure, further comprising the step of:

excavating guiding pilot tunnels at positions where corner portions of a bottom floor plate of the concrete box are located, respectively.

The scope of the invention recited in Claim 6 resides in the construction method of an underground structure, further comprising the step of:

implementing a pipe roof as a protecting work, prior to the towing of the concrete box.

The scope of the invention recited in Claim 7 resides in the construction method of an underground structure, further comprising the steps of:

implementing a box type roof, as a protecting work, comprising juxtaposed roof-aimed tubes made of rectangular steel pipes, prior to the towing of the concrete box; and

sequentially advancing the roof-aimed tubes.

As described above, the construction method of an underground structure of the present invention is capable of constructing a structure in a ground by towing the structure made of a full-size precast concrete, such as in case of excavatingly advancing to construct an underground

structure having a greater width in a ground under a railroad, road, or the like in a direction traversing it, which construction method is extremely high in safety, which construction method never requires large-scale facilities unlike a shield tunneling method, and which construction method never leaves a traversing site in an unstable state over a long period of time unlike an open cut method configured to form a large ditch in a ground while conducting an earth retainment in a manner to form a concrete structure by a mold in the ditch, and unlike a cast-in-place concrete method based on a temporary support by a false-work, configured to construct the false-work and excavate a ground therein to thereby form a concrete structure.

## BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

FIG. 1 is a side view of an underground structure showing a mutual towing method as a construction method of an underground structure according to the present invention;

FIG. 2 is a side view of an underground structure showing a one-side towing method as a construction method of an underground structure according to the present invention;

FIG. 3 is a side view of an underground structure showing a divisional one-side towing method as a construction method of an underground structure according

to the present invention;

FIG. 4 is a side view of an underground structure showing an endless self advancing method as a construction method of an underground structure according to the present invention;

FIG. 5 is a front view of a guiding pilot tunnel of a mountain tunnel type;

FIG. 6 is a front view of a guiding pilot tunnel of a circular steel pipe type;

FIG. 7 is a front view of a combination of a pipe-roof protecting work and guiding pilot tunnels;

FIG. 8 is a front view of a combination of a box type roof protecting work and guiding pilot tunnels;

FIG. 9 is a front view of a rectangular arrangement of box type roof protecting works;

FIG. 10 is a side view of an underground structure showing a towing method combined with a box type roof protecting work of a gate-like arrangement, as a construction method of an underground structure according to the present invention;

FIG. 11 is a side view of an underground structure showing a towing method combined with a box type roof protecting work of a rectangular arrangement, as a construction method of an underground structure according to the present invention;

FIG. 12 is a side view of an underground structure showing an endless self advancing method combined with a

box type roof protecting work, as a construction method of an underground structure according to the present invention;

FIG. 13 is an explanatory view of a towing jack;

FIG. 14 is an explanatory view of a fixing member;

FIG. 15 is a side view of an underground structure in a finally docked state;

FIG. 16 is a side view of an underground structure showing a jacking method as a conventional example; and

FIG. 17 is a front view of a pipe-roof protecting work in the jacking method as the conventional example.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described hereinafter in detail with reference to the accompanying drawings. FIG. 1 to FIG. 3 show implementing methods of underground structures according to the present invention, respectively, all of which are of a towing type, where the method is a mutual towing method in case of FIG. 1, the method is a one-side towing method in case of FIG. 2, and the method is a divisional one-side towing method in case of FIG. 3 in which a precast concrete box (box culvert) is dividedly implemented such as in case of a longer implementing extension or in case of a greater towing resistance force.

In this figure, reference numerals 1 designate precast concrete boxes (box culverts), respectively, each

having a cutting edge 2 based on a steel-made hood attached to a front end of the concrete box, and these precast concrete boxes are installed at both sides of a traversing site under an upper traffic 8 such as a rail track(s), respectively, such that towing directions of the precast concrete boxes are opposed to each other.

One of the concrete boxes 1 has a rear portion provided with towing jacks 10 attached thereto, and the other concrete box 1 has a rear portion provided with fixing members 11 attached thereto, in a manner that PC wires 12 to be utilized as towing members are penetrated through the traversing site, and ends of each PC wire 12 are fixed to the associated towing jack 10 and fixing member 11, respectively.

Each towing jack 10 is a center hole jack as shown in FIG. 13, and each fixing member 11 comprises a fixing block 11a, and wedges 11b each of a split pin type in a wedge shape to be pushed into each hole of the fixing block 11a. Each wedge 11b is pushed into the associated hole of the fixing block 11a while penetrating one of twisted threads constituting the PC wire 12 through the wedge 11b itself, thereby fastening the applicable PC wire 12 to the associated fixing member 11 by virtue of a wedge effect.

Also, in case of fixing each PC wire 12 to the associated towing jack 10, that portion of the PC wire 12, which is penetrated through the towing jack 10 and exposed, is fastened thereto by attaching another fixing member 11

to that portion.

In this way, the towing jacks 10 are used to mutually tow concrete boxes 1 to be constructed at both sides of the traversing site, in a box-by-box manner utilizing the cooperating one of the boxes as a reactive resistance body.

In case of towing each concrete box 1, excavation of a portion of a ground at the cutting edge 2 is conducted from an inside of the cutting edge to thereby form a space in the soil and sand in front of it, and the concrete box 1 is correspondingly advanced by an excavated distance. The concrete box 1, which acts as the reactive resistance body, is that before conduction of such excavation. The excavation is conducted by using an excavator, or by a human power, as the case may be.

In this figure, reference numerals 7 designate foundation concretes, and reference numeral 8 designates an upper traffic such as a rail track. Further, reference numerals 13 each designate an earth retaining member for forming a starting vertical shaft 3 or arrival vertical shaft 9, and the earth retaining member is face cut to form an opening into which the applicable concrete box 1 is penetrated.

Further, reference numerals 5, 6, and 7 designate a reaction wall provided in a starting vertical shaft 3, a strut, and a foundation concrete, respectively. It is noted that the concrete box 1 is longitudinally extended by concatenating rectangular unit boxes 1a each having a

length of about 1 to 2 meters.

In the figure, reference numeral 16 designates a pipe roof, and provision is made of a protecting work by such a pipe roof 16.

Shown in FIG. 15 is a finally docked state. In this case, starting vertical shafts 3 are provided at both sides of the underground structure, respectively, to establish an implementing section A therebetween.

In turn, FIG. 2 shows an embodiment configured to install a reactive body at a side of arrival vertical shaft 9, to install a concrete box 1 provided with a rear portion having towing jacks 10 attached thereto at a side of starting vertical shaft 3, and to penetrate PC wires 12 as towing members through a traversing portion, in a manner to fix ends of each PC wire 12 to the associated towing jack 10 and the associated fixing member 11 provided on the reactive body, respectively.

In this embodiment, the reactive body placed at the side of arrival vertical shaft 9 is constituted of a reactive box 14. This reactive box 14 has a reactive resistance enhancing key 14a.

The concrete box 1 is towed by the PC wires 12 from the side of starting vertical shaft 3 toward the arrival side, by using the reactive box 14 as an anchor.

It is noted that, as a technique to obtain a reactive force in the one-side towing method shown in FIG. 2, it is also possible to obtain a reactive force in a way different

from the reactive box 14, in an exemplary manner to directly obtain a reactive force from a natural ground at the backside, to provide a retaining wall to obtain a reactive force therefrom, or to form an embankment to obtain a reactive force therefrom.

FIG. 3 shows a divisional one-side towing method configured to divide the targeted concrete box into multiple concrete boxes $1_1$ and $1_2$, and to provide intermediate pushing jacks 15 as propulsive jacks between the multiple concrete boxes 1.

The method is further configured to install a reactive box 14 (one box) as a reactive body at a side of arrival vertical shaft 9, and to attach towing jacks 10 to a rear portion of the rear concrete box $1_2$, such that ends of PC wires 12 connected to the towing jacks 10 are fastened to the reactive box 14 at the side of arrival vertical shaft 9, through fixing members 11, respectively.

The towing jacks 10 are operated while using the rear concrete box $1_2$ as a reactive body to thereby tense up the PC wires 12, the front box $1_1$ is then excavatedly advanced by the intermediate pushing jacks 15 while simultaneously fixing the towing jacks 10, and then, the intermediate pushing jacks 15 are made free and the rear concrete box $1_2$ is advanced by the towing jacks 10.

Also, in case that the targeted concrete box is provided as three or more divisional boxes, the boxes are sequentially advanced by intermediate pushing jacks 15 from

the foremost box, in a manner to advance the last concrete box by the towing jacks 10.

Further, although not shown, this divisional towing method is applicable even to the mutual towing method shown in FIG. 1, such that the targeted concrete box is divided into multiple concrete boxes $1_1$, $1_2$, ⋯, and intermediate pushing jacks 15 as propulsive jacks are arranged between the multiple concrete boxes $1_1$, $1_2$, ⋯, in a manner to allow for addition of a step to sequentially advance the multiple concrete boxes by the applicable intermediate pushing jacks 15, respectively, in a box-by-box manner from the foremost concrete box.

Thus, FIG. 3 shows a situation of the divisional one-side towing method configured to implement the targeted precast concrete box (box culvert) by dividing it such as in case of a longer implementing extension or in case of a greater towing resistance force.

FIG. 4 shows an endless self advancing method configured to arrange multiple precast concrete boxes $1_1$, $1_2$, $1_3$, ⋯, $1_n$ in a row in the longitudinal direction while providing intermediate pushing jacks 15 between adjacent two precast concrete boxes, respectively, in a manner to attach a cutting edge 2 to the foremost concrete box $1_1$.

The method is further configured to attach towing jacks 10 to a rear portion of the rearmost concrete box $1_n$ and to attach fixing members 11 at a front portion of the foremost concrete box $1_1$, and to mutually couple the towing

jacks 10 and fixing members 11 by PC wires 12, respectively. The PC wires 12 are provided by penetrating through the above arranged concrete boxes $1_1$, $1_2$, $1_3$, ⋯, $1_n$.

The endless self advancing method has a principle similar to that of a movement of a spanworm. Namely, its tail portion is firstly fixed (for reactive force) to advance a head portion. Next, the head portion is fixed (for reactive force) to retract the tail portion, to move forward. This motion is repeated for advancement.

In turn, all the concrete boxes $1_1$, $1_2$, $1_3$, ⋯, $1_n$ are advanced by constant distances, respectively, in a manner that a portion of a ground at the cutting edge 2 is excavated from an inside of the cutting edge such that the applicable concrete box is advanced by a constant distance by extending strokes of intermediate pushing jacks 15 interposed between the applicable concrete box and the following concrete box, sequentially from the foremost concrete box $1_1$ to the rearmost concrete box $1_2$, and upon completion of the advancement of all the concrete boxes $1_1$, $1_2$, $1_3$, ⋯, $1_n$ by the constant distances, respectively, the same operation as the above is repeated from the foremost concrete box to the rearmost concrete box.

To advance the foremost or first box $1_1$ in that case, the fixing members 11 and towing jacks 10 are made free, and the intermediate pushing jacks 15 between the first concrete box $1_1$ and the second concrete box $1_2$ are operated by using, as a reactive force, a frictional resistance

caused by self-weights of the backward concrete boxes $1_2$, $1_3$, ⋯, $1_n$ and the soil pressure.

Next, advancement of the second box $1_2$ is conducted such that the fixing members 11 and towing jacks 10 are fixed to the PC wires 12 and the towing jacks 10 are operated to tense up the PC wires 12, respectively, and the intermediate pushing jacks 15 between the second concrete box $1_2$ and the third concrete box $1_3$ are operated by using, as a reactive force, the first concrete box $1_1$ and the third concrete box $1_3$.

In this way, the third concrete box and the concrete boxes subsequent thereto are also advanced; and further, for propulsion of an applicable concrete box closer to the rearmost concrete box, self-weights of the concrete boxes subsequent to the applicable concrete box are insufficient, so that this insufficient weight is supplemented by transmitting jack reactive forces to those concrete boxes forward of the applicable concrete box by the PC wires 12.

For propulsion of the rearmost concrete box $1_n$, the towing jacks 10 are operated to tense up the PC wires 12, thereby pulling the concrete box $1_n$ forwardly to advance it. At the time that the advancement of the rearmost concrete box $1_n$ is finished, the propulsion at one time is completed.

Meanwhile, as shown in FIG. 5 and FIG. 6, guiding pilot tunnels 18 are provided by excavation, at positions where corner portions of a bottom floor plate of the concrete box 1 are located, respectively. Examples of the

guiding pilot tunnel 18 include various types, and the example of FIG. 5 shows a case of arch type tunnel configured to conduct earth retainment by lining up H-shaped steels or liner plates 19 next to each other as a false-work, while conducting excavation.

FIG. 6 shows a case of circular guiding pilot tunnel using steel pipes 20 or Hume pipes. The method for burying the steel pipes is configured to use a propulsion device having a propulsion cylinder and a leading pipe having a cutter head at a front end, in a manner to set the propulsion device and the leading pipe at a side of the starting vertical shaft 3, to rotate the cutter at the front end of the leading pipe by a hydraulically driven motor disposed therein to thereby excavate a ground in front of the face of the cutter to start propulsion, and to subsequently retract a propulsive jack of the propulsion device such that a steel pipe 20 as a pipe to be buried and internally including a screw is connected to the leading pipe. The excavated earth removal is controlled in exhaustion amount commensurately with an excavated amount, by a dedicated motor separate from the motor for rotating the cutter.

Such an operation is repeated to sequentially connect steel pipes 20 and to propel to bury them, thereby causing the leading pipe to arrive at the arrival vertical shaft 9, whereupon only the leading pipe is withdrawn from the arrival vertical shaft 9. In this way, the steel pipes 20

are buried between the starting vertical shaft 3 and arrival vertical shaft 9.

In FIG. 5 and FIG. 6, reference numeral 25 designates a guiding H-shaped steel, and reference numeral 26 designates a guide rail.

As shown in FIG. 7, these guiding pilot tunnels 18 are frequently implemented in combination with a protecting work based on a pipe roof 16.

Prior to towing of the concrete box 1, the upper protecting pipe roof 16 is constructed in an upper portion of the ground for constructing an underground structure therein.

The upper protecting pipe roof 16 is constructed in a manner to propel each steel pipe in a tunnel axial direction by a propulsion device so that multiple steel pipes are arranged substantially horizontally in the same manner, to establish a roof of an underground structure. Further, under the steel pipe arranged at each end of the upper protecting pipe roof 16, multiple steel pipes are arranged substantially in the vertical direction, thereby constructing a sidewall protecting pipe roof for protecting each sidewall of the underground structure.

To be conducted subsequently to the above operation and under the upper protecting pipe roof 16, is excavation for provision of horizontal boreholes for penetrating PC wires 12 therethrough, respectively, and for provision of guiding pilot tunnels 18. Then, towing jacks 10 are

installed at a rear end of the concrete box 1 constructed at the starting vertical shaft 3, and the PC wires 12 are penetrated through the horizontal boreholes and the guiding pilot tunnels 18, thereby towing the concrete box 1. In this way, the PC wires are concentratedly penetrated through the insides of the guiding pilot tunnels 18. This enables to reduce the number of horizontal boreholes to be bored.

In case of towing the concrete box 1, the concrete box 1 at the side of the starting vertical shaft 3 is towed by the PC wires penetrated through the guiding pilot tunnels 18 based on steel pipes 20, respectively. This causes the concrete box 1 to be advanced by using the guiding pilot tunnels 18 as guides, respectively, thereby achieving an excellent directionality and improving an implementing accuracy.

In addition to the protecting work based on the pipe roof 16, examples of the protecting work include box type roofs 17 as shown in FIG. 8 and FIG. 9, respectively.

Each box type roof 17 is based on a construction method configured to protect a rail track by a roof called a box type roof constituted of roof-aimed tubes 17a made of rectangular steel pipes, respectively, instead of by a pipe roof 16, in a manner to install a structure body under the rail track while forwardly pushing this box type roof 17, so that implementation of a protecting work for an underground structure to be excavatedly advanced in the

ground can be conducted in a safe, reliable, and inexpensive manner with a thinner overburden, simultaneously with excavating advancement of the underground structure, without implementing the protecting work as a separate construction. The roof-aimed tubes 17a are each a box-shaped tube made of steel pipe having a substantially square cross section, such that the tubes are continuously formed in a longitudinal direction through hook-like joints at side surfaces of the tubes and are provided with friction cutter plates at upper surfaces of the tubes, respectively, in a manner to allow the tubes to be sequentially connected in the longitudinal direction to thereby bury a required length of the thus extended roof-aimed tube, and to juxtapose the extended roof-aimed tubes in the lateral direction via joints. Examples of the juxtaposition of the roof-aimed tubes include a gate type in a shape combining an upper floor plate and sidewall plates of the concrete box 1 correspondingly to its shape as shown in FIG. 8, a type in a shape combining an upper floor plate, sidewall plates, and a bottom floor plate of the concrete box 1, i.e., a rectangular arrangement corresponding to a cross-sectional shape of the concrete box 1 as shown in FIG. 9, and, in addition to the above, a straight line type (not shown).

FIG. 10 shows a towing method configured to combine the one-side towing method shown in FIG. 2 with the box type roof 17, where the roof-aimed tubes 17a have upper

surfaces provided with friction cutter plates 21, respectively, in a manner to allow the tubes to be sequentially connected in the longitudinal direction to thereby bury a required length of the thus extended roof-aimed tube, and to juxtapose the extended roof-aimed tubes in the lateral direction via joints.

Interposed between the concrete box 1 and the roof-aimed tubes 17a are small jacks 22, respectively.

The small jacks 22 are sequentially extended to push forward the roof-aimed tubes 17a one by one in a manner to use the concrete box 1 as a reactive force while leaving the friction cutter plates 21, respectively, and once all the roof-aimed tubes 17a are advanced, the small jacks 22 are contracted and then the concrete box 1 is excavatedly advanced by the towing jacks 10 and PC wires 12.

In this way, advancement of roof-aimed tubes 17a and towing of the concrete box 1 are alternately repeated, and those roof-aimed tubes 17a exposed at the arrival vertical shaft 9 are sequentially removed. Further, once the front end of the concrete box 1 is caused to arrive at the arrival vertical shaft 9, the cutting edge 2 and the like are removed, and the implementation is completed by appropriately conducting back grouting.

The embodiment of FIG. 10 corresponds to a situation adopting a natural ground as a reactive body at a side of arrival vertical shaft 9.

The embodiment of FIG. 11 corresponds to a situation

where roof-aimed tubes 17a as shown in FIG. 9 are arranged in a rectangular shape.

In this case, earth retaining members 13 such as steel pile planks are hammer-set at both sides of the upper traffic 8 such as a railroad to thereby construct the starting vertical shaft 3 and arrival vertical shaft 9, in a manner to install a propulsion device in the starting vertical shaft 3 so as to press roof-aimed tubes 17a into the ground toward the arrival vertical shaft 9. The roof-aimed tubes 17a have upper surfaces having friction cutter plates 21 attached thereto, respectively, which are pushed forward together with the roof-aimed tubes 17a and disposed in the ground, and the friction cutter plates 21 are then fixed at the side of the starting vertical shaft 3 by stop members, respectively. These friction cutter plates 21 are used to cut connection between the box type roof 17 and concrete box 1 and the soil and sand therearound.

The roof-aimed tubes 17a are arranged in a rectangular shape correspondingly to a contour of the concrete box 1 to be towed as shown in FIG. 9, and earth retaining members 23 are disposed at face portions of the ground enclosed in the roof-aimed tubes 17a, respectively, to thereby confine that portion of the soil and sand interposed between the earth retaining members 23, within the box type roof 17. The earth retaining members 23 may be fastened to each other, by tie-rod members.

Next, the front end of the concrete box 1 is joined

to or abutted to the rear end of the box type roof 17 having been previously pushed forward, and the towing jacks 10 are operated to tow the concrete box 1 from the starting vertical shaft 3 toward the arrival vertical shaft 9 by the PC wires 12.

Simultaneously with towing of the concrete box 1, the box type roof 17 is also pushed forward, and the earth retaining members 23 disposed at both sides of the ground enclosed by the box type roof 17 are also pushed forward simultaneously with pushing forward of the box type roof 17 without conducting excavation at the face portions, thereby simultaneously extruding the soil and sand between the earth retaining members 23. In this case, the connection between the box type roof 17 and concrete box 1 and the soil and sand therearound has been cut by the friction cutter plates 21 as described above, so that the box type roof 17 and concrete box 1 are towed smoothly.

Once the box type roof 17 and the soil and sand, which are enclosed by the box type roof 17 and which have been extruded simultaneously with the box type roof 17, have arrived at the arrival vertical shaft 9, the soil and sand are simultaneously excavated and exhausted simultaneously with removal of the box type roof 17 at the arrival vertical shaft 9.

Then, the concrete box 1 is further towed until the front end thereof is caused to arrive at the arrival vertical shaft 9, thereby completing propulsion of the

entire length of the concrete box 1.

FIG. 12 shows the endless self advancing method shown in FIG. 4 adopting the box type roof 17 as a protecting work instead of the pipe roof 16, where the multiple precast concrete boxes $1_1$, $1_2$, $1_3$, ⋯, $1_n$ are arranged while providing intermediate pushing jacks 15 between adjacent two precast concrete boxes, respectively, in a manner to attach a cutting edge 2 to the foremost concrete box $1_1$, to install roof-aimed tubes 17a in front of it, and to interpose small jacks 22 between the foremost concrete box $1_1$ and the roof-aimed tubes 17a, respectively. In this case, the arrangement manner of the roof-aimed tubes 17a may be a lateral straight line shape, a gate shape, or a rectangular shape.

Towing jacks 10 are attached to a rear portion of the rearmost concrete box $1_n$ and fixing members 11 are attached to a front portion of the foremost concrete box $1_1$, and the towing jacks 10 and fixing members 11 are coupled to one another by PC wires 12, respectively, through the above arranged concrete boxes $1_1$, $1_2$, $1_3$, ⋯, $1_n$.

The small jacks 22 are sequentially extended to push forward the roof-aimed tubes 17a one by one in a manner to use the concrete boxes $1_1$, $1_2$, $1_3$, ⋯, $1_n$ as a reactive force, and once all the roof-aimed tubes 17a are advanced, the small jacks 22 are contracted and then the concrete boxes $1_1$, $1_2$, $1_3$, ⋯, $1_n$ are excavatedly advanced by the towing jacks 10 and PC wires 12.

The excavating advancement of the concrete boxes $1_1$, $1_2$, $1_3$, ⋯, $1_n$ is conducted such that all the concrete boxes $1_1$, $1_2$, $1_3$, ⋯ , $1_n$ are advanced by constant distances, respectively, in a manner that a portion of a ground at the cutting edge 2 is excavated such that the applicable concrete box is advanced by a constant distance by extending strokes of intermediate pushing jacks 15 interposed between the applicable concrete box and the following concrete box, sequentially from the foremost concrete box $1_1$ to the rearmost concrete box $1_2$, and upon completion of the advancement of all the concrete boxes $1_1$, $1_2$, $1_3$, ⋯, $1_n$ by the constant distances, respectively, the same operation as the above is repeated from the foremost concrete box to the rearmost concrete box.

To advance the foremost or first box $1_1$ in that case, the fixing members 11 and towing jacks 10 are made free, and the intermediate pushing jacks 15 between the first box $1_1$ and the second box $1_2$ are operated by using, as a reactive force, a frictional resistance caused by self-weights of the backward boxes $1_2$, $1_3$, ⋯, $1_n$ and the soil pressure.

Next, advancement of the second box $1_2$ is conducted such that the fixing members 11 and towing jacks 10 are fixed to the PC wires 12 and the towing jacks 10 are operated to tense up the PC wires 12, respectively, and the intermediate pushing jacks 15 between the second box $1_2$ and the third box $1_3$ are operated by using, as a reactive force,

the first box $1_1$ and the third box $1_3$.

In this way, the third box and the boxes subsequent thereto are also advanced; and further, for propulsion of an applicable box closer to the rearmost box, self-weights of the boxes subsequent to the applicable box are insufficient, so that this insufficient weight is supplemented by transmitting jack reactive forces to those boxes forward of the applicable box by the PC wires 12.

For propulsion of the rearmost box $1_n$, the towing jacks 10 are operated to tense up the PC wires 12, thereby pulling the box $1_n$ forwardly to advance it. At the time that the advancement of the rearmost concrete box $1_n$ is finished, the propulsion at one time is completed.

In this way, advancement of roof-aimed tubes 17a and towing of the concrete box 1 are alternately repeated, and those roof-aimed tubes 17a exposed at the arrival vertical shaft 9 are sequentially removed.

What is claimed is:

1. A construction method of an underground structure, comprising the steps of:

installing precast concrete boxes each having a cutting edge based on a steel-made hood attached to a front end of the concrete box, at both sides of a traversing site, respectively, such that towing directions of the precast concrete boxes are opposed to each other;

attaching a towing jack to a rear portion of one of the precast concrete boxes, attaching a fixing member to a rear portion of the other, and penetrating a PC wire as a towing member through the traversing portion in a manner to fix ends of the PC wire to the towing jack and the fixing member, respectively; and

using the towing jack to mutually tow the precast concrete boxes in a box-by-box manner utilizing the cooperating one of the precast concrete boxes as a reactive resistance body.

2. A construction method of an underground structure, comprising the steps of:

installing a reactive body at a side of an arrival vertical shaft, and installing a precast concrete box having a rear portion provided with a towing jack at a side of a starting vertical shaft;

penetrating a PC wire as a towing member through a traversing portion, and fixing ends of the PC wire to the towing jack and a fixing member provided on the reactive

body; and

using the towing jack to tow the precast concrete box from the side of the starting vertical shaft toward the side of the arrival vertical shaft by the PC wire, by using the reactive body as an anchor.

3. The construction method of an underground structure according to claim 1 or 2, further comprising the steps of:

dividing the concrete box into multiple concrete boxes, and locating intermediate pushing jacks between adjacent two concrete boxes, respectively; and

operating the applicable intermediate pushing jack to excavatingly advance the concrete box forward of the applicable intermediate pushing jack in a box-by-box manner, and finally making the intermediate pushing jacks free and advancing the rearmost concrete box by the towing jack.

4. A construction method of an underground structure, comprising the steps of:

arranging multiple precast concrete boxes in a row in the longitudinal direction while providing intermediate pushing jacks between adjacent two precast concrete boxes, respectively, in a manner to attach a cutting edge to the foremost concrete box, to attach a towing jack to a rear portion of the rearmost concrete box, to attach a fixing member at a front portion of the foremost concrete box, and to mutually couple the towing jack and fixing member by a PC wire through the arranged multiple concrete boxes;

advancing all the concrete boxes by constant

distances, respectively, in a manner that a portion of a ground at the cutting edge is excavated from an inside of the cutting edge such that the applicable concrete box is advanced by a constant distance by extending a stroke of the intermediate pushing jack interposed between the applicable concrete box and the following concrete box, sequentially from the foremost concrete box to the rearmost concrete box, and upon completion of the advancement of all the concrete boxes by the constant distances, respectively, the same operation as the above is repeated from the foremost concrete box to the rearmost concrete box; and

conducting the above steps in such a manner that, for propulsion of an applicable concrete box closer to the rearmost concrete box, self-weights of the concrete boxes subsequent to the applicable concrete box are insufficient, so that this insufficient weight is supplemented by transmitting a jack reactive force to those concrete boxes forward of the applicable concrete box by the PC wire, and for propulsion of the rearmost concrete box, the towing jack is operated to tense up the PC wire, thereby pulling the rearmost concrete box forwardly to advance it.

5. The construction method of an underground structure according to any one of claims 1 to 4, further comprising the step of:

excavating guiding pilot tunnels at positions where corner portions of a bottom floor plate of the concrete box are located, respectively.

6. The construction method of an underground structure according to any one of claims 1 to 4, further comprising the step of:

implementing a pipe roof as a protecting work, prior to the towing of the concrete box.

7. The construction method of an underground structure according to any one of claims 1 to 4, further comprising the steps of:

implementing a box type roof, as a protecting work, comprising juxtaposed roof-aimed tubes made of rectangular steel pipes, prior to the towing of the concrete box; and

sequentially advancing the roof-aimed tubes.