

Construction Method for Heavy Load Bearing Pipe Curtain

Technical Field

[0001] The present invention relates to the technical field of building construction, and specifically to a construction method for a heavy load bearing pipe curtain.

Background

[0002] A pipe curtain method is commonly used for large cross-sectional tunnel construction all over the world, the principle thereof is using a professional pipe jacking machine, densely arranging steel pipes with larger diameters underground for pre-forming of a steel pipe curtain, and then carrying out underground tunnel excavation under the protection of the steel pipe curtain. The method has an advantage of using miniaturized apparatus for building complicated large cross-sectional tunnels. The pipe curtain can be seen as forming of horizontally driven steel pipe piles, and these densely arranged steel pipe piles, with the help of other measures, form an earth spalling stop and water stop forepoling support structure so that a large cross-sectional tunnel can be safely built in a soft earth formation. No road excavation and water level descending work are required in the pipe curtain construction process, noise and shock are not generated and the influence on environment is small. Besides, the construction method features high precision and strong support safety performance.

[0003] The city environment is more and more complex and the geological conditions are becoming increasingly complicated as well due to the existence of large-scale railway stations, heavy railway and highway traffic, dense buildings and various pipelines. With the continuous underground space exploitation in scale and range, more and more projects are using the pipe curtain method to build large cross-sectional tunnels in complex conditions, the pipe curtain method is used to build, in a super shallow tunnelling manner, underground tunnels in for example large-scale railway stations, railways, highways and other important buildings, and the requirements for formation disturbance during construction are getting higher and higher due to the complex conditions.

[0004] The exits of some tunnels are located in high rock slopes or in rock formations so that a pipe curtain receiving well cannot be disposed, which is undesirable for normal construction.

Summary

[0005] It is an object of the present invention to provide a construction method for heavy load bearing pipe curtain, wherein the construction method is suitable for complex geological conditions.

[0006] The below technical solution is adopted in order to achieve the above mentioned objective: a construction method for heavy load bearing pipe curtain, characterized by using automatic return pipe jacking machine, comprising the steps as follows:

[0007] (1) site measurement: investigating and exploring the hydrology geology and the surroundings within the pipe curtain construction boundary to obtain the construction site data, and the position and quantity of the pipe curtains and the jacking force of the pipe jacking machine are configured as a function of the obtained data;

[0008] (2) construction preparation: moving the machine used in the construction process to the construction site and fixing in place;

[0009] (3) steel pipe jacking: adjusting the position of the pipe jacking machine and jacking a first steel pipe in;

[0010] (4) steel pipe fixing: placing and fixing another steel pipe at the rear end of the pipe that is jacked in step (3);

[0011] (5) re-jacking: re-jacking the pipe of step (4) using the pipe jacking machine;

[0012] (6) repeating steps (4) and (5) to finish the jacking of a complete pipe curtain, and returning the pipe jacking machine;

[0013] (7) moving the pipe jacking machine to the next position, and repeating steps (3)-(6);

[0014] (8) repeating step (7) until all pipe curtains are jacked in;

[0015] (9) filling by grouting.

[0016] The principle and beneficial effect of the present solution lie in that different types of pipe jacking machines can be selected via this method for smooth jacking according to the formation geology, underground obstacles and the like, and multiple pipe jacking machines work simultaneously to accelerate the construction process; meanwhile, the method and technology have less disturbance to the formation and can satisfy the land subsidence requirements under complicated circumstances; the method also has the advantages of low noise, slight shock, less environmental influence, smaller land subsidence, higher support safety performance (higher than that of, for example, a grouting method, a horizontal jet-grouting pile method and a pipe roof method), no traffic blockage, as well as reasonable and controllable compositive cost. In addition, as an automatic return

pipe jacking machine is used for jacking according to this application, the machine can automatically return when finishing jacking so that no receiving well is required to be disposed, accordingly, the present application is in particular suitable for pipe curtain construction in road cut sections with high slopes and for circumstances where the pipe curtain exit is located within a rock formation.

[0017] Further, step (2) includes the substeps as follows:

[0018] 1) site preparation: hardening the site of an open excavation area at a tunnel entrance, and arranging a work platform and a back wall for pipe curtain construction;

[0019] 2) pipe jacking platform preparation: embedding screws and installing corbels on the jacking surface and the back wall, and installing main beams and a formed steel platform;

[0020] 3) equipment preparation: the equipment to be prepared including a pipe jacking machine, a counter-force support apparatus, a hoisting apparatus, a jacking platform apparatus and a slurry precipitation system.

[0021] Further, the jacking speed in step (4) includes a jacking speed of 3-5mm/min in an initial stage and a jacking speed of 10-20 mm/min when entering the tunnel.

[0022] Further, the work platform of step (2) is a movable overhead platform and consists mainly of a sliding pipe jacking guide rail, a height adjustment bolster, a support bracket, a bracket pulley and a bracket guide rail; wherein the support bracket is mounted on the bracket pulley, horizontally slidable along the bracket guide rail, and is locked by a fixing lock during the pipe jacking construction.

[0023] Further, in step (9), fine aggregate concrete is used for filling.

[0024] Further, a connecting plate is reserved on a base plate of the work platform, and the guide rails are laid by means of bolted connection.

[0025] Further, a thick concrete water stop wall is poured at the tunnel entrance, two water stop rubber rings are fitted outside the wall, and steel plates are arranged between the rubber rings for separating and fixing same.

[0026] Further, step (5) includes a measurement step and a deviation rectification step.

[0027] Further, in step (5), measurement starts when a pipe is jacked by 500 mm, and then measurement and record are made every 300 mm during the pipe jacking.

[0028] Further, in step (5), the pipe curtain jacking speed is 10-20 mm/min.

Brief Description of the Drawings

[0029] Fig. 1 is a perspective view of the counter-force bracket in accordance with the construction method for a heavy load bearing pipe curtain in embodiment 1 of the present

invention;

[0030] Fig. 2 is a construction effect view of the construction method for a heavy load bearing pipe curtain in embodiment 1 of the present invention;

[0031] Fig. 3 is a perspective view of the rotatable cutter head in accordance with the construction method for a heavy load bearing pipe curtain in embodiment 2 of the present invention;

[0032] Fig. 4 is a structural schematic of the rotatable cutter head in accordance with the construction method for a heavy load bearing pipe curtain in embodiment 2 of the present invention.

Detailed Description of the Embodiments

[0033] Now, specific embodiments will be further described below in detail.

[0034] The reference numerals in the drawings of description include: counter-force bracket 1, pipe curtain 2, cutter head main body 3, support plates 4, connector bracket 5, tool body 6, connecting plate 7, driving gear 8, driven gear 9, connecting rod 10, screw 12, connecting ring 13, and nut 14.

[0035] Embodiment I

[0036] The embodiment is substantially as illustrated in Fig. 1 and Fig. 2: a construction method for heavy load bearing pipe curtain, including the steps as follows:

[0037] (1) site measurement: the hydrology geology and the surroundings are investigated and explored within the pipe curtain construction boundary to obtain the construction site data and the position and quantity of the pipe curtains and the jacking force of the pipe jacking machine are configured as a function of the obtained data;

[0038] (2) construction preparation: the machine used in the construction process is moved to the construction site and fixed in place;

[0039] (3) steel pipe jacking: a jack is used to jack an automatic return slurry balance machine and the steel pipes into a rock formation or a mountain, wherein the jacking direction is parallel with the direction of the tunnel to be excavated;

[0040] (4) steel pipe fixing: another steel pipe is placed and fixed at the rear end of the pipe that is jacked in in step (3);

[0041] (5) re-jacking: the pipe of step (4) is re-jacked using the pipe jacking machine;

[0042] (6) steps (4) and (5) are repeated to finish the jacking of a complete pipe curtain;

[0043] (7) the pipe jacking machine is moved to the next position, and steps (3)-(6) are repeated;

[0044] (8) step (7) is repeated until all pipe curtains 2 are jacked in;

[0045] (9) filling by grouting: in step (9), fine aggregate concrete is used for filling, and

[0046] wherein, the calculation formula of the maximum jacking force F of step (1) is as follows: $F = F_1 + F_2$;

[0047] $F_1 = \pi/4 \times D_1 \times P$;

[0048] $P = K_o \cdot \gamma \cdot H_o$;

[0049] $F_2 = \pi D \cdot f \cdot L$;

[0050] wherein F represents the maximum jacking force, F_1 represents the end resistance, F_2 represents the side wall frictional resistance; D represents the external diameter of a pipe; P represents the control earth pressure; K_o represents the static earth pressure coefficient, the value generally being 0.55; H_o represents the height from the ground to the center of a tunnel, the value being 3m; γ represents the weight of sandstone; f represents the comprehensive frictional resistance on the external surface of the pipe and is determined by a geological exploration report; and L represents the jacking distance.

[0051] The jacking speed of step (4) includes a jacking speed of 3-5 mm/min in an initial stage and a jacking speed of 10-20 mm/min when entering the tunnel.

[0052] Step (2) further includes the substeps as follows: 1) site preparation: the site of the open excavation area at the tunnel entrance is hardened, and the work platform and the back wall are arranged for pipe curtain construction;

[0053] 2) pipe jacking platform preparation: boreholes are drilled on the jacking surface and the back wall for embedding screws and installing corbels, and main beams and formed steel platform are installed to form the counter-force bracket 1; specifically, the counter-force bracket, 10m in length and 6m in height, is welded by means of HN450 formed steel and is meanwhile supported in an inclined strutted manner by double rows of 300H formed steel with a height of 2.2m and 5m respectively, and is embedded with a depth of 30cm, in an inclined strutted manner, into the base plate concrete of the open excavation tunnel. The counter force at the rear seat is 2.0-2.5 times of the total jacking force.

[0054] 3) equipment preparation: the equipment to be prepared include a pipe jacking machine, a counter-force support apparatus, a hoisting apparatus, a jacking platform apparatus and a slurry precipitate system; an electric mobile platform is adopted during the pipe jacking, and the platform, consisting of a support truss, a hoisting apparatus, and a mobile platform etc., can move vertically and laterally by means of an electric guide chain; and two work platforms are disposed in each cross section;

[0055] 4) water stop treatment at the tunnel entrance: a concrete water stop wall with a thickness of 350 mm is poured at the tunnel entrance, and two water stop rubber rings are fitted outside the wall. Steel plates having a size of $\delta = 10$ mm are provided among the rubber rings for separating and fixing same.

[0056] Step (5) further includes a measurement step and a deviation rectification step, specifically, measurement starts when a pipe is jacked 500 mm in, and then measurement and record are made every 300 mm during the pipe jacking. A leverage principle is adopted in the deviation rectification device, wherein pivots are provided on an external shield at the rear end of the device, and a radial deviation rectification oil cylinder at the rear end is used to drive the tail of an internal shield to move so that a cutter head generates an action in the reverse direction for changing the attitude of the machine head and the deviation rectification purpose is thus reached. A laser target is mounted within the machine head, a terminal console is provided to monitor the space position, and a hydraulic deviation rectification device in the machine head itself is used for deviation rectification to ensure the rectification precision.

[0057] A speed control is applied to the pipe curtain jacking machine and the speed is controlled to be different in two stages. When the machine head enters the tunnel, the speed is controlled to be 3-5 mm/min. The factors influencing the speed are: a) the thickness of the cement mortar brickwork cut by the cutter head; when the rotating speed of the cutter head is 2.2 rpm, the jacking speed is 3-5 mm/min, and the brickwork is cut with a thickness of 1.4-2.3 mm to be crushed into coarse powder for easily bringing out the slurry; b) the torque generated by the machine head, when penetrating into the earth, overcoming the rotation of the cutter head; a friction generated by the weight of the machine head between the machine and the guide rail influences the torque, which will be large when the cutter head penetrates too deep into the earth, as a result, the machine head rotates. When the first pipe enters the tunnel, the speed of the cutter head is controlled to be 10-20 mm/min and not be too large, as the main tasks during this stage are targeting the pipe center and aligning the elevation, with a deviation of ± 5 mm.

[0058] The tunnel is then closed for further construction, the machine head is slowly and horizontally pushed into the tunnel, without rotating the cutter head, to penetrate into a 1:2 cement mortar clay brickwork. The slurry inlet flow during the jacking process is controlled to be 0.4-0.6m³/min to be acted on a lubrication cutter, the brickwork is cut and a mixture of sand, slurry and water etc. is brought out. At this time, the slurry flows out and is separated into two parts, a part of which flows into a reservoir well from outside the

machine head, wherein the slurry is discharged by a 4-inch slurry pump arranged in the well into a sand-water separation device; and another part of which is discharged into the sand-water separation device by means of the machine head slurry outlet pipe.

[0059] The slurry inlet flow is controlled to be $0.6\text{--}0.8\text{ m}^3/\text{min}$ upon initial jacking, and the volume-weight ratio of the slurry is 1.20; the slurry is discharged from a slurry outlet pipe of the pipe jacking machine to a sand-water separation device, and the pressure in the slurry bin therein is controlled to be 40KPa.

[0060] Thixotropic slurry is used during the jacking process for reducing the frictional resistance, and is conveyed by a centrifugal pump into the pipeline under a pit. The thixotropic slurry of the present embodiment mainly consists of bentonite, and is prepared by adding alkali and water (the mix proportion of the thixotropic slurry is: water : bentonite = 8:1). A retarder and a plasticizer are necessarily to be added in the mixture for maintaining the fluidity when used in construction. When the pipe jacking is completed, for the tunnel portion having insufficient earth stability or the over-excavated portion, a grouting replacement is performed to the slurry unfavorable to a slurry jacket within the earth formation range, the mix proportion of the replacing cement slurry is: cement: fly ash: water = 1: 0.7: 1. The grouting pressure and the pipes to be grouted are determined on the basis of the actual earth site.

[0061] The construction method of the present embodiment is adopted so that different types of pipe jacking machine can be selected for smooth jacking according to formation geology, underground obstacles and the like, and multiple pipe jacking machines work simultaneously to accelerate the construction process; meanwhile, the method and technology have less disturbance to the formation and can satisfy the land subsidence requirements under complicated circumstances; the method may also have the advantages of low noise, slight shock, less environmental influence, smaller land subsidence, higher support safety performance (higher than that of, for example, a grouting method, a horizontal jet-grouting pile method and a pipe roof method, etc.), no traffic blockage, as well as reasonable and controllable composite cost. In addition, as an automatic return pipe jacking machine is used for jacking according to this application, the machine can automatically return when finishing jacking so that no receiving well is required to be disposed, accordingly, the present application is in particular suitable for pipe curtain construction in road cut sections with high slopes and for circumstances where the pipe curtain exit is located within a rock formation.

[0062] Embodiment II

[0063] As shown in Figs. 3 and 4, a returnable pipe jacking device is adopted in the present embodiment for pipe jacking. The returnable pipe jacking device comprises an outer housing and an inner housing. The inner housing, disposed inside the outer housing, is provided with a power mechanism, a transmission mechanism and cutter heads. It is the prior art and is well known to those skilled in the art that the power mechanism drives the cutter heads to rotate by means of the transmission mechanism, and the details will thus not be repeated herein. A rotatable cutter head is disposed at a end portion of the power mechanism. The rotatable cutter head comprises a cutter head main body 3, and a plurality of support plates 4 are arranged along the circumferential direction of the cutter head main body 3. Specifically, the number of the support plates is four according to the present embodiment, and the four support plates 4 are uniformly arranged along the circumferential direction of the cutter head main body 3. One end of the support plate 4 is hinged to the cutter head main body 3 via a hinge (not shown in the figures). A chute is provided in a radial direction of the cutter head main body 3, and a connecting plate 7 is arranged on one end face thereon to be slidably connected with the cutter head main body 3 via the chute, wherein the connecting plate is sliding along the radial direction of the cutter head main body 3. In an original state, the support plate 4 is coplanar with the cutter head main body 3, the connecting plate 7 is away from the end portion of the cutter head main body 3 center point and the support plate such that the support plate 4 cannot rotate around its hinged position with the cutter head main body. Specifically, the power mechanism comprises a motor (not shown in the figures) fixed inside the inner housing. An output shaft of the motor is connected with a driving gear 8 via flat keys, a driven gear 9 is disposed at the center of the rotatable cutter head, and the driving gear 8 is engaged with the driven gear 9.

[0064] An oil cylinder (not shown in the figures) is also provided inside the inner housing, and baffle plates are welded on an output shaft of the oil cylinder. A screw 12 is connected in the middle part of the cutter head main body 3, and the screw 12 is coaxially connected with the driven gear 9. The screw 12 is screw-thread fitted with a nut 14 which is a hex nut 14 according to the present embodiment, one end of a baffle plate abuts one side of the hex nut. The present embodiment further comprises a connecting ring 13 which is in coaxial connection and rotated together with the nut 14. The present embodiment further comprises a connecting rod 10, one end of which is hinged to the connecting ring 13 and the other end of which is hinged to the connecting plate 7.

[0065] A plurality of cutting tools are provided around the rotatable cutter head, and the number of the cutting tools according to the present embodiment is four. The four cutting

tools are uniformly arranged along the circumferential direction of the cutter head main body 3 and are spaced apart from the support plates 4. The cutting tool comprises a tool main body 6 and a connecting bracket 5, the tool is connected with the connecting bracket 5 and is hinged to the cutter head main body 3.

[0066] The detailed process of the embodiment is as below: when a pipe jacking machine is working, the inner housing is positioned inside the outer housing and the rotatable cutter head is positioned at the port of the inner housing, the support plate 4 is coplanar with the cutter head main body 3 hereupon, and the diameter of the circle enclosed by the support plates 4 is equal to that of the outer housing, that is, the cutter head has a maximum contact with rock and earth, etc. so as to support the earth during the jacking process. Upon jacking, the power mechanism drives the rotatable cutter head to rotate for cutting or crushing earth or rock by means of cutting tools, a main jack applies an axial force to the pipe jacking machine through the steel pipe so that the pipe jacking machine moves axially, thereby achieving the effect of jacking the steel pipe in. The oil cylinder is started when the machine is required to return, a piston rod of the oil cylinder extends out to push the baffle plates to abut the nut 14, at this time, the nut 14 is screw-thread fitted to the screw 12. The rotatable cutter head rotates and drives the screw 12 to rotate, while at this time, the nut 14, as abutting the baffle plate, cannot rotate but can move axially. That is to say, the nut moves along the axial direction of the screw 12 and drives the connecting ring 13 to move, and the connecting ring 13 drives the connecting plate 7 to move towards the direction close to the center of the cutter head main body 3, namely, the angle formed between the connecting rod and the screw becomes smaller. The support plate 4 rotates around its hinged position with the cutter head main body 3 under the pressure of the rock earth until the support plate is perpendicular to the cutter head main body 3. In this way, the area of the entire rotatable cutter head decreases so as to be retracted into the inner housing, the return process is thus completed.

[0067] The pipe jacking machine of the present embodiment is adopted so that, when jacking the steel pipe, the nut 14 does not move and the connecting rod 10 forms a stable triangular structure between the screw 12 and the cutter head main body 3, at this time, the middle part of the connecting plate 7 is at the hinged position between the support plate 4 and the cutter head main body 3 to support the support plate 4 and prevent the support plate 4 from rotating. The circle formed by the plurality of support plates 4 can support the earth during pipe jacking. While when the pipe jacking machine is required to return, the piston rod of the oil cylinder is merely driven to be extended out for driving the connecting plate 7

to move towards the center of the cutter head main body 3, and the support plate 4 rotates so that the diameter of the rotatable cutter head decreases to be retracted into the outer housing, and the return process is thus completed.

[0068] The above descriptions are only the embodiments of the present invention, and common knowledge such as specific technical solutions and/or features that are well known in the art is not described in detail herein. It should be noted by those skilled in the art that several changes and improvements may be made without departing from the technical solution of the present invention, and these changes and improvements may also be regarded as the protection scope of the present invention and will not influence the effect of the present invention and the patent practicability. The protection scope of the present application shall be determined by the terms of the claims, and the records such as specific mode of carrying out the invention may be used to interpret the content of the claims.

CLAIMS

1. A construction method for heavy load bearing pipe curtain, characterized by using an automatic return pipe jacking machine, and comprising the steps as follows:

(1) site measurement: investigating and exploring the hydrology geology and the surroundings within the pipe curtain construction boundary to obtain the construction site data, and the position and quantity of the pipe curtain and the jacking force of the pipe jacking machine being configured as a function of the obtained data;

(2) construction preparation: moving the machine used in the construction process to the construction site and fixing in place;

(3) steel pipe jacking: adjusting the position of the pipe jacking machine and jacking a first steel pipe in;

(4) steel pipe fixing: placing and fixing another steel pipe at the rear end of the pipe that is jacked in in step (3);

(5) re-jacking: re-jacking the pipe of step (4) using the pipe jacking machine;

(6) repeating steps (4) and (5) to finish the jacking of a complete pipe curtain, and returning the pipe jacking machine;

(7) moving the pipe jacking machine to the next position, and repeating steps (3)-(6);

(8) repeating step (7) until all pipe curtains are jacked in;

(9) filling by grouting.

2. A construction method for heavy load bearing pipe curtain of claim 1, characterized in that, step (2) includes the substeps as follows:

1) site preparation: hardening the site of an open excavation area at a tunnel entrance, and arranging a work platform and a back wall for pipe curtain construction;

2) pipe jacking platform preparation: embedding screws and installing corbels on the jacking surface and the back wall, and installing main beams and formed steel platform;

3) equipment preparation: the equipment to be prepared including a pipe jacking machine, a counter-force support apparatus, a hoisting apparatus, a jacking platform apparatus and a slurry precipitate system.

3. A construction method for heavy load bearing pipe curtain of claim 2, characterized in that, the jacking speed of step (4) including a jacking speed in an initial stage of 3-5 mm/min and a jacking speed when entering the tunnel of 10-20 mm/min.

4. A construction method for heavy load bearing pipe curtain of claim 3, characterized in that, the work platform of step (2) is a movable overhead platform and consists mainly of a

sliding pipe jacking guide rail, a height adjustment bolster, a support bracket, a bracket pulley, and a bracket guide rail; wherein the support bracket is mounted on the bracket pulley, horizontally slidable along the bracket guide rail and is locked by a fixing lock during the pipe jacking construction.

5. A construction method for heavy load bearing pipe curtain of claim 4, characterized in that, in step (9), fine aggregate concrete is used for filling.

6. A construction method for heavy load bearing pipe curtain of claim 5, characterized in that, a connecting plate is reserved on a base plate of the work platform, and the guide rails are laid by means of bolted connection.

7. A construction method for heavy load bearing pipe curtain of claim 6, characterized in that, a thick concrete water stop wall is poured at the tunnel entrance, two water stop rubber rings are fitted outside the wall, and steel plates are arranged between the rubber rings for separating and fixing same.

8. A construction method for heavy load bearing pipe curtain of claim 7, characterized in that, step (5) further includes a measurement step and a deviation rectification step.

9. A construction method for heavy load bearing pipe curtain of claim 8, characterized in that, in step (5), measurement starts when a pipe is jacked 500 mm in, and then measurement and record are made every 300 mm during the pipe jacking.

10. A construction method for heavy load bearing pipe curtain of claim 9, characterized in that, the pipe curtain jacking speed of step (5) is 10-20 mm/min.