

THREE DIMENSIONAL MULTI-PHASE TUNNELING
METHOD AND EQUIPMENTS THEREOF

Description

5

Technical Field

The present invention relates to a tunneling method; and, more particularly, to a three dimensional multi-phase tunneling method and equipments thereof, wherein a drilling
10 and blasting process can be carried out simultaneously during excavating a pilot tunnel by means of tunnel boring machine (TBM), thereby is capable of reducing the period and the cost of excavation.

15 Background Art

In a rock tunneling work, for solving a problem on a ground vibration and improving a tunneling excavation rate, a Tunnel Boring Machine/New Austrian Tunneling Method (TBM/NATM) has recently been proposed. According to the
20 combined TBM/NATM method, a pilot tunnel is excavated using the TBM while the remaining section for enlargement is excavated using the NATM.

For the conventional tunnel excavation or the blasting for enlargement using a TBM pilot tunnel, the drilling and
25 blasting has been generally carried out by using a longitudinal drilling and blasting method for achieving a drilling and blasting in a tunneling direction (hereinafter, referred to as a longitudinal drilling and blasting method). In most of tunneling faces, a leg drill or a jumbo drill is
30 used to drill charge holes in an area to be excavated, depending on work situation.

A conventional longitudinal drilling and blasting method will be described in brief in conjunction with Fig. 1 and Figs. 2A to 2D.

35 Referring to Fig. 1, the charge holes 4 are drilled according to a pattern, where reference numerals indicated

in each circle assigned to each charge hole 4 denote a sequential blasting order.

Figs. 2A to 2D are schematic views respectively illustrating sequential steps of a conventional longitudinal drilling and blasting method. Here, reference numerals 1, 2, 3, 4 and 5 denote a pilot tunnel, an upper half section, a lower half section, charge holes, and a line drilling area, respectively.

According to the conventional drilling and blasting method, first, the charge holes 4 are drilled in the upper half section 2 as shown in Fig. 2A. The drilling work is carried out using leg drills for drilling a predetermined length of tunnel or jumbo drills for drilling rockbolt holes or charge holes, depending on the work situation.

Thereafter, a charging of the charge holes 4 is carried out as shown in Fig. 2B. At this time, the blasting delay order of the charge holes 4 is determined. The blasting delay order for generating the blast sequentially, starting at an area nearest to a free face of a pilot tunnel 1 in order to obtain a free face effect provided by a pilot tunnel 1, is made such that the sequential blast is processed from the innermost area nearest to the pilot tunnel 1 to the outermost area farthest from the pilot tunnel 1. At this time, the blasting delay order of the line drilling area 5 is also determined. In similar to that of the pilot tunnel 1, the blasting delay order of the outermost section is made such that it corresponds to the order of a bottom portion, a lower portion and a ceiling portion. On the basis of the determined blasting delay order, a charging of the line drilling area 5 is carried out. In this case, a predetermined precise blasting powder is charged in the blasting portions of the line drilling area 5, taking into consideration a loosened area of rock generated after the drilling and the blasting as shown in Fig. 2B.

After completing the charging, a blast is carried out in the planned blasting delay order. A muck produced after

the blasting is then removed as shown in Fig. 2C. Thereafter, the charge holes 4 having a predetermined length are drilled in the full section as shown in Fig. 2D. The above procedures are repeated to achieve a desired tunneling.

5 In the conventional longitudinal blasting method for excavating a tunnel in the above-mentioned sequence, a blast vibration is propagated to a face of the ground through the entire length of the tunnel because the charge holes 4 are arranged in a tunneling direction. As a result, the blast
10 vibration of the ground may occur when a blast pressure and energy is transmitted from a blast source to rock masses. Due to such the ground vibration, structures installed on an area adjacent to the portion disposed over the tunnel and the other establishments sensitive to the vibration may be
15 severely damaged.

In the conventional longitudinal drilling and blasting method, the blasting for enlargement of the TBM pilot tunnel is carried out only in the longitudinal direction after removing a rail for a TBM muck car, so that a one-time
20 drilling length is limited. And an overbreak and a drilling time may be increased due to the increase of the excavation length. It is inconvenient for the drilling of the charge holes after the excavation due to a severe roughness of a tunnel face, and the length of drilling for the charge holes
25 in the tunneling direction is limited. Furthermore, drilling-charging-blasting-muck removing procedures should be repeatedly carried out in the tunnel excavating work after a pilot tunnel has been excavated using the TBM. As a result, the pilot tunnel may be inefficiently used. These
30 result in a long construction period and a high construction expense. In addition, since the muck stacked on the area beneath the excavating section is loaded into dump trucks one by one using an appropriate mechanical equipment, it takes a long time to remove all the muck so that next
35 process can not be carried out until all the mucks are removed.

In this process of removing the muck, a number of supportable subsequent vehicles and mobilities are limited, thereby serving as an obstructing factor in improvement of the excavating length. In addition, as the excavating length becomes increased, an overbreak may be also inevitably increased. Although the overbreak in a predetermined area is allowed so as to extend the excavating length, an amount of the muck is increased and it takes much time to remove the muck. Therefore, there is a limitation on an increase of the excavating length in view of tunnel excavation cycle time.

To solve the above problem, a bi-directional drilling and blasting method and charge hole drilling apparatus is disclosed in Korea Patent No. 98-143712. Figs. 3A and 3B show patterned charge holes, respectively, whereas Fig. 3C shows two sectional views, respectively taken along a line A-A and a line B-B of Figs. 3A and 3B. Figs. 4A to 4D are schematic views respectively illustrating sequential steps of a bi-directional drilling and blasting method.

Referring Figs. 3A to 3C, lattice-shaped charge holes are drilled in a radial direction of the pilot tunnel 7, and then a drilling is carried out in a longitudinal direction in an outermost tunneling section. At this time, reference numerals, indicated in each circle, assigned to each of charge holes 9 denote the blasting order.

Transverse charge holes 9 are radially drilled in an upper half section 8 in a direction perpendicular to a longitudinal direction in a pilot tunnel 7 excavated by the TBM. Simultaneously, longitudinal charge holes are also drilled in an outermost section 10 in the longitudinal direction as shown in Fig. 4A. A charging of the longitudinal and transverse charge holes is carried out as shown in Fig. 4B. Then, a blast is carried out. Referring to Fig. 4C, the muck produced by the blast is removed using an appropriate mechanical equipment, for example, a load head bucket. The line charge holes 5 are drilled again in a

predetermined portion of the outermost section 10 as shown in Fig. 4D.

Although the conventional bi-directional drilling and blasting method has an advantage that drilling and blasting
5 period can be shortened, the muck should be removed in the same manner as the longitudinal drilling and blasting method, so that there is few efficiency of the tunnel excavation cycle time. That is, as an excavating length becomes long, the muck removal time to be required is also increased.

10 Furthermore, a drilling equipment is needed to carry out the bi-directional drilling and blasting for enlargement. Since it is difficult for installing the drilling equipment on the TBM to drill the radial holes on the lower half section of the tunnel because of the blasting pattern in the
15 bi-directional drilling and blasting method, the drilling should be processed with another drilling equipment, e.g., the jumbo drill so that the efficiency of the drilling equipment is decreased. Moreover, it is somewhat difficult for the jumbo drill to approach the pilot tunnel made by the
20 TBM owing to the size and the drilling position is also hardly confirmed even if drilled with the jumbo drill.

Although the small size jumbo drill is used, there is also several problems that cables attached on the jumbo drill and water supplying pipes should be entered the tunnel
25 in the drilling process, whereby these cables and pipes should be removed outside the tunnel to prohibit the damage from the blasting process. Therefore, it takes long time for the excavation and moreover, it is difficult to proceed the drilling process and the tunnel boring process
30 simultaneously. In addition, because the longitudinal drilling and blasting method is still used at the lower half section, this method has the limitation to shorten the drilling time to be spent.

As described above, the drilling and blasting are
35 processed after the complete tunnel boring by the TBM in longitudinal drilling and blasting methods or in bi-

directional drilling and blasting method, the only radial drilling process can be carried out during the tunnel boring by the TBM, but the blasting process should be carried out after completing the tunnel boring.

5 If the drilling and blasting process and the tunnel boring process are carried out simultaneously, facilities required for the TBM tunneling, i.e., electricity supply cable, water supply pipe, air supply pipe and so on, are damaged and the rail for the muck car is buried due to the
10 blasting for enlargement inevitably.

Disclosure of Invention

It is, therefore, an object of the present invention to provide a three dimensional multi-phase tunneling method to
15 enhance a period and a cost of tunnel excavation, wherein a drilling and blasting is carried out simultaneously during excavating a pilot tunnel.

It is another object of the present invention to provide equipments in use for the method, which are capable
20 of effectively improving a tunnel excavation rate and a removal of muck.

In accordance with an embodiment of the present invention, there is provided a method for excavating a tunnel, comprising the steps of: a) drilling an oblique
25 charge hole on an upper half section in a pilot tunnel being excavated by a tunnel boring machine (TBM) and drilling an outermost charge hole to a predetermined length in a tunneling direction (longitudinal direction) at an outermost tunneling section during excavating the pilot tunnel, and
30 charging and blasting the upper half section, wherein the oblique charge hole is turned at a predetermined angle from a transverse direction to a longitudinal direction; and b) charging and blasting the lower half section except the central portion apart at a distance from the tunnel face.

35 In accordance with another embodiment of the present invention, there is provided a device for tunneling,

comprising: a main body of tunnel boring machine (TBM) excavating a pilot tunnel while advancing in tunneling direction, and having a trailer; a drilling means for drilling oblique holes on a upper half section of the pilot
5 tunnel while the TBM excavates the pilot tunnel, and the drilling means being installed on the main body of the TBM, wherein the oblique holes are turned at predetermined angle from a transverse direction to a longitudinal direction; a first rotating means for rotating the drilling means in the
10 oblique direction and a circumferential direction; a muck removing means, installed in the bottom area of the lower half section, for carrying the muck produced by the blast outside the tunnel; and a second rotating means for rotating a bucket, installed on the front of a loader, for loading
15 the muck easily at the narrow area of the upper and the lower half section by rotating the bucket at a predetermined angle in a horizontal plane.

Brief Description of the Drawings

20 Other objects and aspects of the invention will become apparent from the following description of the embodiments with reference to the accompanying drawings, in which:

Fig. 1 is a schematic view of a conventional longitudinal drilling and blasting pattern;

25 Figs. 2A to 2D show a sequential steps of a conventional longitudinal drilling and blasting method;

Figs. 3A to 3C illustrate schematic views of a conventional bi-directional drilling and blasting patterns;

30 Figs. 4A to 4D depict a sequential steps of a conventional bi-directional drilling and blasting method;

Figs. 5A and 5D represent a schematic views of drilling and blasting patterns in accordance with the present invention;

35 Fig. 6 presents a perspective view of the three dimensional multi-phase tunneling method in accordance with the present invention;

Figs. 7A to 7D provide a sequential steps of the three dimensional multi-phase tunneling method in accordance with the present invention;

Fig. 8A is a schematic view of a two way rail track system of the conventional tunneling method;

Figs. 8B and 8C are schematic views of a three way rail track system of the three dimensional multi-phase tunneling method in accordance with the present invention;

Fig. 8D shows a schematic view of a variable ladder for use in the three dimensional multi-phase tunneling method in accordance with the present invention;

Figs. 9A to 9C illustrate a diagram illustrating a structure of a wedge coupler for use in the present invention;

Figs. 10A to 10G depict schematic views of sequential steps of removing muck produced by the three dimensional multi-phase tunneling method in accordance with the present invention;

Figs. 11A to 11C represent schematic views of a tunnel boring machine (TBM) for use in the conventional and present invention;

Figs. 12A to 12D present schematic views of a rotating means for use in the three dimensional multi-phase tunneling method in accordance with the present invention;

Figs 13 and 14 provide schematic views of a carrying means of the muck in use for the three dimensional multi-phase tunneling method in accordance with the present invention;

Fig. 15 is a perspective view of a ventilation duct system of a three dimensional multi-phase tunneling method in accordance with the present invention; and

Figs. 16A to 16C show schematic views of lining form for use in the three dimensional multi-phase tunneling method in accordance with the present invention.

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Best Mode for Carrying out the Invention

Figs. 5A and 5B are schematic views illustrating a drilling and blasting patterns of three dimensional multi-phase tunneling method in accordance with the present invention.

5 Referring to Figs. 5A to 5D, based on the fact that a blast vibration is propagated at a larger magnitude in a tunneling direction through a length direction of charge holes, the charge holes 22 are in advance drilled at a predetermined length in an oblique direction during
10 excavating the pilot tunnel by a tunnel boring machine (TBM). That is, the oblique charge hole is slanted from a transverse direction to a longitudinal direction on a tunneling section. The longitudinal charge holes 23 for a smooth blasting are drilled to a predetermined length at an
15 outermost tunneling section and then a first oblique blasting and longitudinal blasting for enlargement is carried out in the region that is hundreds of meters distant from a TBM tunnel face. Thereafter, the longitudinal charge holes 26 are drilled again on the lower half section except
20 the central portion to a predetermined length at the zone of blasting for enlargement (hereinafter, referred to as a NATM tunnel face) and then a second blasting for enlargement is carried out. And finally, using the transverse charge holes drilled in advance on the central portion of the lower half
25 section, a third blasting for enlargement is carried out after completing the pilot tunnel 21 by the TBM and dismantling a rail for a muck car. Therefore, a tunnel excavation cycle time and an expense for excavation can be reduced.

30 The three dimensional multi-phase tunneling procedures will be described more detailed with reference to Fig. 6 and Figs. 7A to 7D.

Referring to Fig. 6, there is provided a perspective view of present invention showing whole the charge holes and
35 a muck removing means for carrying the muck.

To begin with, the oblique holes 22 having a

predetermined angle and length are drilled in advance on the upper half section by using a jumbo drill mounted near a head or back-up system of the TBM, and then line drilling holes 23 in the outermost tunneling section are drilled
5 longitudinally to reduce an overbreak at the region which is hundreds of meters distant from the TBM tunnel face. In accordance with a preferred embodiment of the present invention, the length of the line drilling hole (l_a) is 2~4 m correspondent to the oblique charge holes of which the
10 distance is 2~4 m as represented in Fig. 7A. At this time, the end of the longitudinal charge hole should be correspondent to the end of the oblique charge hole as shown a dotted line "a" in Fig. 7A.

It is preferable that the angle of the oblique charge
15 holes are appropriately determined in order to concentrate the muck produced by the blast in the middle of the tunnel face after blasting as shown in Fig. 7B. In the embodiment of the present invention, the oblique charge hole is slanted to the entrance of the tunnel, of which angle is of $20^\circ \sim 40^\circ$.
20 And next, a second blasting for enlarging the lower half section except the central portion is carried out, at the region which is tens of meters distant from the NATM tunnel face, by the longitudinal drilling and blasting method as shown in Fig. 7D. Finally, a third blasting for enlarging
25 the central portion of the lower half section is carried out by the transverse drilling and blasting method, of which the holes are in advance drilled.

Although there is provided a single blasting for the first blasting in accordance with the embodiment of the
30 present invention, a double blasting can be carried out to obtain longer length of a tunnel excavation and to remove a remained rock completely by longitudinal drilling and blasting method for the outermost tunneling section after single blasting is finished as described in Fig. 7C.
35 However, this method should be done at the same time of the second blasting in consideration of the amount of the muck

to be transported. This makes the remained rock removed clearly so that the length of the tunnel excavation can be increased.

Another embodiment of the present invention will be described with reference to Figs. 9A to 9C providing a wedge coupler for the present invention to control the charging of charge holes.

When drilling the oblique charge holes 22, for maximally reducing the cycle time of tunnel excavation, the oblique charge holes 22 is in advance drilled to a length identical to a sum of the length of a blasting hole and a rockbolt hole 24, to thereby maximize the efficiency of the pilot tunnel. That is, the combined charge hole/rockbolt hole is used as a blasting hole for a first oblique blasting. After a second precise blasting of the outermost tunneling section, the combined charge hole/rockbolt hole can be re-used as the rockbolt hole. Therefore, since it is unnecessary to carry out an additional rockbolt drilling for the stabilization of the excavated tunneling section, the rockbolt drilling time can be remarkably reduced. At this time, in an intersection of the combined oblique charge hole/rockbolt hole and the longitudinal charge hole, the flow of water can be observed at the oblique charge holes since the water generated from the drilling work is flowed in the longitudinal drilling. Therefore, if the intersection occurs, that problem can be solved by again carrying out the longitudinal drilling at an area apart from a first charge hole.

After completing the drilling of the oblique charge holes 22 and the longitudinal charge holes, an equipment for removing the muck produced by the blast is installed on the floor of the tunnel. By appropriately adjusting the section for enlargement up and down in a lower half section of the pilot tunnel, a carrier 33 of the equipment 31 for removing the muck can be protected from a blasting pressure and the falling muck due to the blasting.

As shown in Fig. 14, a rail 432 is laid on both sides of the floor of the pilot tunnel and a wheel 433A is attached on the lower portion of the equipment to thereby enable the equipment to be moved. Furthermore, a carrier 433 includes a connecting ring for continuously connecting to the end of the equipment and a container 434 with a space to contain the muck, wherein the container 434 is laid on the upper portion of the carrier 433 and can be lift up on dump trucks. At this time, a rubber 435 is attached to the inside of the carrier 433 in contact with the outside of the container 434 to thereby minimize a damage and a noise caused by the dispersion of the falling muck.

As shown in Figs. 9A to 9C, after installing the equipment 31 for removing the muck, the oblique charge holes 22 and the longitudinal charge holes 23 are charged. At this time, in the case where the oblique charge holes 22 are drilled longer than they are designed, a wedge coupler is installed at the oblique holes 22 of an oblique blasting section and a sand stemming 25 is carried out to an appropriate length, so that the drilling length for charging can be controlled in order to carry out a first blasting. At this time, a diameter of the wedge coupler is manufactured a few larger than those of the oblique charge holes 22. The wedge coupler 1400 includes a rubber coupler 42, in which a wedge groove 42A is formed, and a wedge 43 which is inserted to the wedge groove 42A of the rubber coupler 42. Therefore, the blasting powder is reliably charged up to the oblique blasting section by the wedge coupler 900 and the sand stemming 25.

Fig. 9C is a diagram illustrating a structure of a wedge coupler 1400 for controlling a charging length in accordance with the present invention.

First, after drilling the oblique charge holes 22, the rubber coupler 42 is inserted into an entrance of the charge holes 22 and is pushed into the oblique charge holes 22 using a scaled pipe 44 according to a design for the

drilling length. Thereafter, the wedge 43 is inserted into the rubber coupler 42 through the scaled pipe 44 using a wedge rod 45, so that the blasting powder is charged up to the drilling length of the oblique blasting section.

5 Although the oblique charge hole is drilled longer than that is designed, using the wedge coupler 1400 can control the drilling length for the charging, so that a precise tunneling is possible.

10 When the charging of the oblique charge holes 22 and the longitudinal charge holes 23 are completed, a first blasting for the oblique blasting and the longitudinal blasting is carried out as described in Fig. 7B.

15 The muck produced by the first blast concentrates to the middle of the tunnel face due to the oblique charge holes 22, to thereby be accumulated into the container 34 laid on the carrier 33 as shown in Fig. 11C. The carrier 33 containing the muck is rapidly withdrawn backward, to thereby obtain a space for next work. The container 34 of the backward-withdrawn carrier 33 is lifted up on the dump trucks, to thereby easily remove the muck as shown in Fig. 11D. Meanwhile, the rest muck, which is not fallen into the carrier, can be loaded into the container 34 using a loader bucket.

25 After carrying out the first blasting, a longitudinal drilling is carried out at the lower half section except the central portion, then a second blasting is carried out.

30 The muck produced by the second blasting for enlargement can be loaded into the container on the carrier. Moreover, the first and the second blasting are carried out simultaneously and the time for a subsequent process, e.g., ventilation process can be reduced.

While the blasting process, a rail switch 890 on a deck plate for facilitating the muck car or a locomotive 500 to move easily is installed in the long tunnel.

35 Referred to Fig. 8A, there is provided a schematic view of a toy way rail track, wherein a deck plate is installed

on every distance of 1 ~ 2 km in the floor of the lower half section of the pilot tunnel and then the muck car or the locomotive can move along mutually. But, in the present invention as referred to Figs. 8B and 8C, a three way rail track is installed, wherein the remained central portion of the lower half section and both sides of the lower half section already excavated is connected each other with a deck plate 870 and the support 880 is set on the ends of the deck plate 870. Therefore, the muck car and carrier are moved easily. In addition, the loader bucket is designed to be rotated in a narrow region of both sides of the lower half section by means of a horizontal rotating device so that the muck produced by the second blasting can be loaded into the muck car easily.

Referring to Fig. 8D, a variable ladder 850 for guiding the equipments for the tunnel excavation, e.g., the jumbo drill and loader with ease can be installed. At this time, a first, a second and a third decks 801, 802 and 803 can be adjustable by using a hinge 804 and two support beams 805 stand beneath the second deck plate 802, which can modulate the height of the deck 801, 802 and 803 by using a bolt 806. Therefore, it is possible to adjust the ladder 850 to the variation of the height of the lower half section.

The second deck plate 802 is connected with a horizontal beam 807 and wheels 808 installed beneath the horizontal beam 807 so that the ladder 850 can be moved easily according to the work situation. And the third deck plate 803 can be up and down to be putted on the lower half section by a hinge 804 and a winch typed wire 809.

Although the blast cannot be carried out in the central portion of the lower half section because of the rail, the both sides of the lower half section can be blasted if the facilities of the TBM, e.g., cables, air or water supplying pipe, ventilation duct and so on, are protected from the blast during excavating the pilot tunnel by the TBM.

That is, the second blasting can be carried out in the

area that is tens of meters distant from the NATM tunnel face at the same time of the first blast, and then it is possible for the third blast to be carried out by a transverse drilling and blasting method after complete
5 tunneling work by the TBM, wherein the drilling can be carried out in advance during excavating the pilot tunnel

Referring back to Figs. 5A to 5D, it is necessary for a smooth blasting in a boundary between the central portion of the lower half section and the both sides to protect the
10 facilities of the TBM during the second blasting. The muck produced by the second blast can be removed at same manner of the first blast as described already. This work is carried out during stabilizing the tunnel, e.g., installing the rockbolt or steel rib, so that the total cycle time can
15 be reduced. The transverse charge holes for the third blasting are drilled in advance using the spare time of the drilling equipment, and then the third blasting is carried out after completing the pilot tunnel by the TBM and dismantling the rail for the muck car.

Referring to the Figs. 10A to 10G, sequential steps of carrying the muck produced in blasting is illustrated in detail, wherein the muck is carried by means of a muck car 28, carriers 27, 33 and a locomotive 500. The muck is loaded into the muck car 28, which moves along the rail, and
25 the locomotive 500 withdraws the muck car 28 or the carrier 27, 33 to the outside tunnel.

The muck produced in excavating the pilot tunnel by the TBM is carried through a conveyor belt to be loaded into the muck car. Then the muck car is withdrawn outside the tunnel
30 by the locomotive 500.

And most of the mucks produced by the first blast are gathered in the container on the carrier 33, and the others remained are loaded by the loader bucket, then the carrier 33 is withdrawn outside the tunnel by the locomotive 300.

35 Next, the muck produced by the second blast is loaded in a bottom carrier 27 or the carrier 33 and these are

withdrawn by the locomotive 500, also. Since the muck produced by the first and the second blasts is loaded into the carrier and withdrawn outside the tunnel rapidly by the locomotive, it is possible to secure the working space for drilling process and reduce the cycle time of tunnel excavation.

If the first and the second blasts are carried out simultaneously to reduce the cycle time, the carrier 33 and the bottom carrier 27 having the muck are withdrawn outside the tunnel rapidly by the locomotive 500.

Referring to the Fig. 11A, there is provided equipments for tunnel excavation including a main body 100 of the TBM for excavating the pilot tunnel with a backup trailer 101 of the TBM and backup facilities 102 of the TBM, a jumbo drill 200 mounted on the predetermined position of the backup trailer 101 of the TBM to drill the oblique charge hole on the upper half section, a first rotating means 300 on the backup trailer 101 of the TBM for rotating and tilting the drill, a muck removing means, disposed on the bottom of the lower half section, for carrying the muck produced by the blast, a second rotating means for rotating the loader bucket to load the muck at the narrow area of the lower half section into the carrier, a locomotive 500 for pulling the muck car and the carrier outside the tunnel, a variable ladder for guiding the whole equipments used in tunneling, and a deck 870 and a rail switch 890 for facilitating the muck car and the carrier to move easily.

Referring to Figs. 11A to 11C, there is shown the main body 100 of the TBM which includes a plurality of cutters 112 with high speed revolution for breaking the rock, a head 110 surrounded by head jacket 116 having a plurality of buckets for carrying the muck backward, a hydraulic cylinder 122 mounted on the rear of the head 110 for making the head 110 move forward, an inner kelly 120 having a driving unit to provide the revolution power to the head 110, a plurality of clamping pads 132 installed on the outer part of the

inner kelly 120, a plurality of pad cylinders 134 disposed on a outer kelly 130 for moving the clamping pads 132 to the radial direction of a pilot tunnel 1, the outer Kelly 130 for supporting the head 110, a belt conveyor 141 and an auxiliary conveyor 142 for carrying the muck in the bucket 114 from the main body 100 of the TBM to the backup trailer 101 of the TBM.

Referring to Fig. 12A, there is shown the jumbo drill 200 mounted on a platform 103 of the backup trailer 101 of the TBM, including a drill 210 for drilling a plurality of charge holes and rockbolt holes, a drifter 220 for driving the drill 210 and a feed cylinder 230 for making the drifter 220 move forward or backward direction. The feed cylinder 230 is controlled by an outer control unit for adjusting the drilling depth according to the condition of the tunnel face.

Although the jumbo drill 200 is mounted on the platform 103 of the backup trailer 101 of the TBM not being interfered with belt conveyor 141 in the embodiment of the present invention, it is possible to install the jumbo drill 200 either on the inner Kelly 120 or the main beam of the main body 100 of the TBM. At this time, why the position of the jumbo drill 200 is apart at a distance from the main body 100 of the TBM is to obtain the sufficient space for drilling.

The operating mechanism of drilling equipment is referred to Figs. 12A to 12C.

The head of the main body 100 of the TBM is progressed by the hydraulic cylinder 122 on the inner Kelly 120 to excavate the pilot tunnel with the cutter of which the driving force is transmitted through the driving unit 124. The muck produced by the excavation is carried by the belt conveyor into the backup facilities 102, and the muck car is withdrawn outside the tunnel by the locomotive.

While the TBM excavates the pilot tunnel, the jumbo drill 200 mounted on the platform of the backup trailer 101 of the TBM drills the oblique charge holes on the upper half

section. At this time, considering the condition of the rock, the rockbolt hole can be drilled either simultaneously or separately with the charge hole.

Referring to Figs. 12A and 12B, there is shown the
5 rotating unit 300 including a rotary gear for rotating the feeder in circumferential direction that has the same central axis to that of the pilot tunnel and is equipped with the jumbo drill 200, a first motor 330 for rotating the feeder individually in the preferable rotation angle of -90°
10 $\sim +90^\circ$, a bracket unit 340 mounted on the rotary frame 320 for rotating the drill obliquely and a stepping motor 350 mounted on the bracket unit 340 for supplying the rotation power in the oblique direction.

Referring to Fig. 12B, there is illustrated the bracket
15 unit 1200 including a bracket 341 for assembling the rotary shaft 320 with bolts of which the shape is concave type like "U" and the hole 341A in the middle of the bracket is pierced, a bearing 346 to be inserted into the hole 341A, a circumscribed gear 342 attached on the spindle of the
20 stepping motor 350, and a ring gear plate 343 having an inscribed gear 344 for fitting the circumscribed gear 342, wherein the inscribed gear is attached on a plate 345.

The angle of the drilling hole is adjusted by the rotation of the rotary gear on the rotary frame 320 driven
25 by the first motor 330 through the rotation unit 300 and the bracket unit 1300. And the oblique charge hole is drilled by the power of the stepping motor 350 through the circumscribed and the inscribed gears 342, 344. At this point, it is preferable that the oblique angle of the ring
30 gear plate 343 driven by the stepping motor 350 is about 20° to 40° . And the oblique charge holes are drilled by the driving force transmitted by the drifter 220 and feed cylinder 230.

Referring to Figs. 13 and 14, there is shown equipments
35 for carrying the muck including a rail 432 installed on both sides of the bottom of the tunnel, a carrier 433 which moves

on the rail 432 by a wheel 433a and has a link to connect another carrier 433, a container 434 on the carrier 433 for the muck being loaded, a rubber plate 435 between the carrier 433 and the container 434 for reducing the impact and the noise, and a spring beneath the carrier for reducing the impact. At this time, the carrier 433 and the container 434 are designed to be loaded the muck as much as possible, e.g., the height of those is little lower than the central horizontal axis of the pilot tunnel.

10 The carrier and the bottom carrier are determined by the work situation of the area of the blasting for enlargement. If the height of the carrier is higher than that of the section of the blasting for enlargement, it is possible to load the muck more but the carrier cannot be
15 protected from the blasting process. Therefore, the carrier should be chosen considering the work situation.

 The equipment 400 having the muck is withdrawn by the locomotive 500. That is, the muck car or the carrier is withdrawn outside the tunnel only one locomotive 500, so
20 that the rate of the operation can be increased.

 The first blasting is carried out after completing the processes of oblique charge holes being drilled, longitudinal holes being drilled and charging of charge holes. And most of the mucks produced by the first blast
25 are accumulated in the middle of the pilot tunnel, e.g., accumulated in the container and the carrier, are withdrawn outside the tunnel by the locomotive.

 It is necessary for the subsidiary facilities to be protected from the blast. In the embodiment of the present
30 invention as described in Fig. 14, the cables, the air supplying pipes and the water supplying pipes are located below the carrier to be protected from the blast so that it is possible to carry out the drilling and blasting with the excavation of the pilot tunnel simultaneously and safely.
35 Therefore, the speed of the excavation of the tunnel is enhanced, and the upper and lower half sections of the pilot

tunnel are utilized efficiently in the present invention than the conventional method. That is, the upper half section is used when the first blasting of the oblique charge holes and the lower half section is used for the
5 second and third blasting, and the subsidiary facilities are protected from the blast by the carrier laid on the lower half part of the pilot tunnel, therefore the efficiency of the pilot tunnel is enhanced remarkably.

Referring to Fig. 15, there is shown a perspective view
10 of a ventilation duct system of a three dimensional multi-phase tunneling method in accordance with the present invention.

The ventilation duct 600 can be installed either in the top area of the pilot tunnel or in the side area. In the
15 embodiment of the present invention, the ventilation duct 600 for the TBM excavation is still used so that the main duct 602 can be separated from the duct 603 placed in the rear of the NATM tunnel face, and then the blasting for enlargement is carried out. Since the ventilation duct 600
20 is designed a zipper 700 type and is hung by a hanger 701 to be separated easily, the blasting for enlargement can be carried out and a dust can be ventilated out. In case of the TBM excavation, it is possible to ventilate the dust produced during the excavation by connecting the main duct
25 602 and the duct 603 placed in the rear of the NATM tunnel face again.

The duct 603 placed in the rear of the NATM tunnel face is used for ventilating the NATM tunnel face, and is used for ventilating the TBM tunnel face by connecting both ducts
30 again. Since the ventilation duct 600 for the TBM excavation is utilized for the blasting for enlargement, the efficiency of the duct can be increased. At this point, the ventilation duct for the TBM tunnel face and for the NATM tunnel face can be installed in parallel. In this case, the
35 contamination material, e.g., dust is ventilated out efficiently by using two ventilation ducts.

Final process of tunnel excavation, i.e., a concrete grouting process is carried out on the outer face of the tunnel after the blast and the installation of the rockbolt and shotcrete grouting is completed. In a conventional method, the concrete grouting can be carried out only after the excavation of pilot tunnel and the blasting for enlargement are completed. However, a special designed lining form is used in the present invention for enabling the transporting facilities, e.g., the muck car, the carrier, to move. Moreover, the concrete lining process can be carried by means of the hinge and winch in the upper part of the lining form as shown in Figs. 16A to 16C.

During the blast for the remained central portion of the lower half section, it is possible for the concrete lining to be protected from the blast by using the shell made of steel, having the wheel and rubber plate.

While the present invention has been described with respect to certain preferred embodiments only, other modifications and variation may be made without departing from the spirit and scope of the present invention as set forth in the following claims.

Claims

1. A method for excavating a tunnel, comprising the steps of:

5 a) drilling an oblique charge hole on an upper half section in a pilot tunnel being excavated by a tunnel boring machine (TBM) and drilling an outermost charge hole to a predetermined length in a tunneling direction (longitudinal direction) at an outermost tunneling section during excavating the pilot tunnel, and charging and blasting the
10 upper half section, wherein the oblique charge hole is turned at a predetermined angle from a transverse direction to a longitudinal direction; and

b) charging and blasting the lower half section except the central portion apart by a predetermined distance from
15 the tunnel face after drilling a longitudinal hole.

2. The method as recited in claim 1, after the step b), further comprising the steps of:

c) drilling a charge hole on a central portion of the
20 lower half section; and

d) carrying out a continuous transverse blasting.

3. The method as recited in claim 1, wherein the step a) includes the steps of:

25 a1) installing a muck car on a rail in the bottom face of the pilot tunnel; and

a2) carrying the muck car with the muck produced by the blasting outside the tunnel by a locomotive.

30 4. The method as recited in claim 1, wherein the step a) further includes the steps of:

a1) installing a carrier on the rail in the bottom face of the pilot tunnel at a zone of a blasting for enlargement after drilling the outermost longitudinal charge hole;

35 a2) blasting for enlargement after charging of the oblique charge hole and the outermost longitudinal charge



hole; and

a3) carrying the carrier with the muck produced by the blast outside the tunnel by the locomotive.

5 5. The method as recited in claim 4, wherein the step a1) includes the step of installing facilities required for the TBM between the carrier and the bottom of the pilot tunnel before installing the carrier.

10 6. The method as recited in claim 4, after the step of a2), further comprising the step of a longitudinal drilling and blasting at a predetermined length again for a remained rock around the tunnel face.

15 7. The method as recited in claim 1 or 2, wherein the step a) includes the step of drilling the oblique hole by means of a jumbo drill mounted on anyone of the site between the backup trailer and the main body of the TBM.

20 8. The method as recited in claim 1 or 2, wherein the drilling length of the oblique hole is identical to a sum of that of the charge hole and a rockbolt hole.

25 9. The method as recited in claim 1 or 2, wherein the oblique charge hole has an predetermined angle to concentrate the muck produced by the blasting for enlargement to the middle of the tunnel.

30 10. The method as recited in claim 9, wherein the predetermined angle is of 20° to 40° .

35 11. The method as recited in claim 1 or 2, wherein the step a) includes the step of carrying out an installation of a wedge coupler at the oblique charge hole of an oblique blasting section and a sand stemming, to thereby insert a blasting powder to the oblique charge hole at a



predetermined length.

12. The method as recited claim 1 or 2, wherein the step a1) includes the steps of:

5 a1) inserting a rubber coupler into an entrance of the charge hole after forming the oblique charge hole and pushing the rubber coupler into the oblique charge hole using a scaled pipe; and

10 a2) inserting a wedge into the rubber coupler using the scaled pipe, to thereby charge a blasting powder up to the oblique charge hole of the oblique blasting section.

13. The method as recited in claim 2, wherein the step a) includes the steps of:

15 a1) installing a ventilation duct at a predetermined area in the tunnel; and

a2) separating a main duct from the duct located in the rear of the tunnel face in the blasting for enlargement at an predetermined region of the rear of the tunnel face.

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14. The method as recited in claim 1, wherein the step b) includes the steps of:

25 b1) installing a bottom carrier on the predetermined region above the bottom of the pilot tunnel at the zone of blasting for enlargement;

b2) drilling a longitudinal charge hole on the lower half section except the central portion;

b3) blasting the longitudinal hole after charging;

30 b4) loading the muck produced by the blast into the carrier or the bottom carrier; and

b5) carrying the carrier or the bottom carrier with the muck outside the tunnel by the locomotive.

15. The method as recited in claim 1, after step b), further comprising the steps of:

e) installing a lining form in the tunnel for enabling



the carrier and the other facilities to move through the lining form; and

f) grouting an inner area of the tunnel with concrete.

5 16. The method as recited in claim 15, wherein a shell made of steel has a shock absorbing material attached on to protect the concrete lining from a third blast, i.e., blasting for enlarging the central portion of the lower half section, and wheels for easy movement.

10

17. A device for excavating a tunnel, comprising:

a main body of tunnel boring machine (TBM) excavating a pilot tunnel while advancing in tunneling direction, and having a trailer;

15 a drilling means for drilling oblique holes on a upper half section of the pilot tunnel while the main body excavates the pilot tunnel, and the drilling means being installed on the main body of the TBM, wherein the oblique holes are turned at predetermined angle from a transverse
20 direction to a longitudinal direction;

a first rotating means for rotating the drilling means in the oblique direction and a circumferential direction;

a muck removing means, installed in the bottom area of the lower half section, for carrying the muck produced by
25 the blast outside the tunnel; and

a second rotating means for rotating a bucket, installed on the front of a loader, for loading the muck easily at the narrow area of the upper and the lower half section by rotating the bucket at a predetermined angle in a
30 horizontal plane.

18. The device as recited in claim 17, wherein the drilling means are installed on anyone of the site selected among an inner kelly, a main beam and a platform of the
35 trailer of the TBM.



19. The device as recited in claim 17, wherein the drilling means includes a drifter for driving the drill and a feed cylinder equipped with the drifter for moving forward and backward.

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20. The device as recited in claim 17, wherein the rotating means includes:

a rotary frame equipped with a rotary gear for rotating the feeder of the drilling means in circumferential direction with an axis parallel to a central axis of the pilot tunnel;

a first motor for rotating the rotary gear in a predetermined angle;

a bracket unit mounted on both side of front of the rotary frame for rotating the drilling means obliquely; and

a stepping motor mounted on the bracket unit for supplying driving force to rotate obliquely in a predetermined angle.

21. The device as recited in claim 20, wherein the bracket unit includes:

a bracket for fixing a supporting handle formed in a groove in the middle of the bracket;

a circumscribed gear installed on the spindle of the stepping motor which pierces the groove in the middle of the bracket; and

a gear frame fixed on the drilling means for matching the circumscribed gear with an inscribed gear.

22. The device as recited in claim 20, wherein the stepping motor supplies a driving force to the bracket unit, being capable of rotating the drilling means to 20° ~ 40° in the oblique direction.

23. The device as recited in claim 17, wherein the muck removing means for the muck includes:



a carrying means for the muck installed on the backup trailer of the TBM for carrying the muck produced by the blast to a predetermined area in the rear of the tunnel face;

5 a rail installed on both sides of the bottom face of the pilot tunnel;

a carrier having wheels for moving on the rail;

a container, installed on the carrier, for loading the muck in the container; and

10 a locomotive, located outside the tunnel, for withdrawing a muck car and the carrier.

24. The device as recited in claim 23, further comprising a first shock absorbing means installed between
15 the carrier and the container for relieving the shock of the muck and a noise.

25. The device as recited in claim 23, further comprising a second shock absorbing means installed beneath
20 the carrier for preventing the rail from the shock of the falling muck.

26. The device as recited in claim 17, further comprising:

25 a ventilation duct installed in a predetermined area in the pilot tunnel for carrying a dust produced in excavating the pilot tunnel and in the blasting for enlargement, which can be separated by a separating means;

a variable ladder for enabling the drilling means and
30 the muck removing means to move easily in the blasting for enlargement; and

a deck and a rail switch for enabling the muck car and the carrier to move easily on another rail by means of installing the rail additionally on the deck by which the
35 central portion of the lower half section and both sides of the lower half section are combined.



27. The device as recited in claim 17, further comprising:

an enlarging means in an upper portion of a lining form
5 for enabling the carrier and the other facilities to move through the lining form; and

a protection means of a concrete lining installed under the lining form for protecting the concrete lining from the third blast.

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28. The device as recited in claim 27, wherein the shell made of steel has mobile wheels, and a shock absorbing material attached on the backside of the protection means of concrete lining.

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