The present invention relates to a tunnel boring machine of the full face rotary type in which roll correction means are provided on the cutterhead support. The roll correction means may also be operative to steer the machine horizontally and/or vertically.
TUNNEL BORING MACHINE ROLL CORRECTION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention pertains to tunnel boring machines of the type which progressively drill a tunnel while passing therethrough. Such machines generally comprise a cutterhead support and a cutterhead rotatably mounted on the forward end of the cutterhead support. Cutting tools such as rolling cutter assemblies are mounted on the forward face of the cutterhead, and these cut away the earth formation as the cutterhead is rotated and driven against the end face of the tunnel. A frame assembly such as a main beam is rigidly connected to the cutterhead support and extends rearwardly therefrom.

A gripper assembly is carried on the frame assembly and is movable toward and away from the cutterhead support along the axis of the machine. The gripper assembly includes a pair of grippers which are radially extensible and retractable for engagement and non-engagement with the tunnel wall. The grippers may be extended into engagement with the tunnel wall to provide thrust reaction as the cutterhead support and attached cutterhead are driven forward against the end face of the tunnel.

The gripper assembly can also provide reaction against the torque of the rotating cutterhead when the grippers are engaged with the wall since it is not rotatable with respect to the frame assembly. However, the grippers often creep along the tunnel in a direction opposite the direction of rotation of the cutterhead so that the machine gradually rolls about its longitudinal axis. Means must then be provided to periodically correct for this roll by restoring the machine to its original position. It is also necessary to provide means for steering the machine in the horizontal and vertical directions.

2. Description of the Prior Art

Several different systems for correcting roll of a tunnel boring machine have been designed. Examples of various roll correcting systems are shown in U.S. Pat. Nos. 2,988,348; 3,061,287; and 3,203,737 as well as in our copending application Ser. No. 363,057. One common feature of these roll correction systems is that they are all built into the gripper assembly. In some of these machines the grippers can be used for horizontal steering. In most of these machines, however, additional horizontal steering means distal the gripper assembly are provided. These may be laterally extensible shoes mounted on opposite sides of the cutterhead support which can be pushed against the tunnel wall to shove the machine to the right or the left. Additionally, vertical steering is provided by some form of jack or ram assembly distal the gripper assembly which is operative to move either the front or the rear of the machine in a vertical direction to turn the machine either upwardly or downwardly. For example, our copending application Ser. No. 363,057, as well as U.S. Pat. No. 3,598,443 show tunnel boring machines in which horizontal and vertical steering shoes are mounted on the cutterhead support.

SUMMARY OF THE INVENTION

In the tunnel boring machine of the present invention a roll correction system is provided on the cutterhead support. In a preferred embodiment the roll correction means is also operative to steer the machine horizontally and vertically.

The bulk of the weight of the tunnel boring machine is located at the front end in the cutterhead and cutterhead support. Thus, the roll correction means on the cutterhead support is more nearly at the center of mass of the machine than a roll correction system requiring use of the gripper assembly. This obviously provides easier and more efficient roll correction.

Additionally, in steering the machine horizontally and vertically, positioning or displacement of the cutterhead is usually of primary concern. Therefore, it is more desirable to steer the machine at the front end, rather than at the rear or midway between, as this allows maximum displacement of the cutterhead with minimum movement of the steering mechanism. The present invention allows the preferred steering means to be incorporated into the roll correction means, all located at the front on the cutterhead support, thereby eliminating unnecessary and wasteful duplication of parts.

In one aspect of the invention, the roll correction means include a pair of generally diametrically opposed control shoes which are extensible in a generally radial direction for engagement with the tunnel wall and retractable for non-engagement. Rolling means interconnecting the cutterhead support and the control shoes are operative to rotate the cutterhead support, and thus the frame assembly and other connected parts, relative to the control shoes about the axis of the cutterhead. The control shoes may be mounted on piston and cylinder assemblies whose radially innermost ends are pivotally connected to the cutterhead for pivoting of the piston and cylinder assemblies in a plane transverse to the axis of the cutterhead. The rolling means may comprise a set of ram assemblies interconnecting respective control shoes with the cutterhead support, lying in a plane transverse to the axis of the cutterhead, and each having a non-radial component.

The control shoes may also be used for horizontal steering if they are located at the sides of the tunnel boring machine. By pushing one of the shoes against the wall of the tunnel while the other shoe is retracted, the front of the machine can be urged in the direction opposite the extended control shoe. In another aspect of the invention, the roll correction means comprises a bottom support assembly mounted on the lower portion of the cutterhead support and movable with respect to the cutterhead support in a plane transverse to the axis of the cutterhead and in a path which partially circumscribes that axis. The bottom support assembly supports the cutterhead support on the invert or floor of the tunnel. The rolling means interconnect the bottom support assembly and the cutterhead support and are operative to roll the cutterhead support about the axis of the cutterhead relative to the bottom support assemblies, the bottom support assembly being held in place against the invert of the tunnel by the weight of the front end of the machine. The bottom support assembly may also be used to effect vertical steering of the machine and can be designed to provide a throughway to the cutterhead for making repairs, etc.

In the preferred embodiments of the invention, the roll correction means includes both control shoes and a bottom support assembly.
It is, therefore, an object of the present invention to provide a rotary tunnel boring machine having improved roll correction means.

A further object is to provide roll correction means located on the cutterhead support of a rotary tunnel boring machine.

Another object of the invention is to provide roll correction means for a tunnel boring machine which are also operative to effect horizontal and vertical steering of the machine.

Still another object of the present invention is to provide a tunnel boring machine with a complete steering and roll correction system located on the cutterhead support.

Other objects, features, and advantages of the invention will be made apparent by the detailed description, the drawings, and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal elevational view of a tunnel boring machine according to the invention taken from one side of the machine and having some parts broken away and other parts shown in section.

FIG. 2 is a partial horizontal sectional view of an enlarged scale taken on the line 2—2 in FIG. 1.

FIG. 3 is a transverse sectional view on an enlarged scale taken on line 3—3 in FIG. 1.

FIG. 4 is a partial longitudinal elevational view of a second embodiment of the invention taken from one side of the machine and having some parts broken away and other parts shown in section.

FIG. 5 is a transverse sectional view on an enlarged scale taken on the line 5—5 in FIG. 4.

FIG. 6 is a diagrammatic illustration of a modification of the machine of FIGS. 1—3 from the same viewpoint as FIG. 3.

FIG. 7 is a diagrammatic illustration of another modification of the machine of FIGS. 1—3 from the same viewpoint as FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, FIGS. 1—3 represent a full face rotary type tunnel boring machine comprising one embodiment of the invention. The machine includes a cutterhead 10 at the forward end. The cutterhead 10 is rotatably mounted on the forward end of a cutterhead support 12 by a suitable bearing assembly diagrammatically represented at 14 for rotation about the axis A, generally coincident with the centerline of the tunnel T being bored. Rigidly connected to the cutterhead support 12 and extending rearwardly therefrom is a frame assembly, in this case a main beam or main frame 16. Carried by the main beam 16 is a gripper assembly including a carriage 18 and a pair of grippers 20. Compartments 22 and 24 are supported on the main beam 16 rearwardly of the gripper assembly to provide a cab for the machine operator and housings for hydraulic pumps and other equipment associated with the machine. The front end of the machine is supported on the invert of the tunnel by support legs 52 and support shoes 54 mounted on the cutterhead support 12.

The machine passes through the tunnel while progressively drilling the same. It is shown in FIG. 1 as it would appear when perfectly aligned in a horizontal tunnel. It will be understood that tunnels frequently are sloped, and not truly horizontal, and also that the machine does not remain in perfect alignment during operation. For example, the machine may roll about its axis A. Additionally, while the axis A, which is fixed with respect to the machine, is always generally aligned with the longitudinal centerline of the tunnel at the location of the machine, it will deviate somewhat from such alignment as the machine shifts about during drilling, as it is steered horizontally and vertically to form the path of the tunnel, which path is not always linear, as it rolls about axis A, etc. For these reasons, the terms "vertical" and "horizontal" will be used herein with reference to the machine itself as it appears in FIG. 1. For example, the axis A will always be considered a horizontal line, and a plane perpendicular to the axis A will be a vertical plane. Terms such as "top," "upward," "side," "laterally," "bottom" etc., will also be used with the machine itself as reference. Finally, the axis A of the cutterhead will be considered the axis of the machine as a whole, and terms such as "radially," "longitudinally" and "circumferentially" will be used with reference to this axis.

Referring again to the drawings, it will be seen that each of the grippers 20 is mounted on an extension 26 of the piston rod of a hydraulic cylinder assembly 28. The cylinder assemblies 28 and grippers 20 are disposed in a sideway guide 30. The cylinder assemblies 28 and guide 30 comprise parts of the gripper assembly and are pivotally mounted on the carriage 18 by a vertical pin 31. This allows pivoting of the guide 30 and cylinder assemblies 28 in a horizontal plane to prevent binding of the gripper assembly during turning of the machine, etc. The grippers 20 may be laterally extended by means of the cylinder assemblies 28 in the guide 30 so that the grippers 20 engage the walls of the tunnel. Similarly, the grippers 20 can be retracted for non-engagement with the wall.

A hydraulic drive cylinder 36 connects each of the grippers 20 to the rear face of the cutterhead support 12. The gripper carriage 18 is mounted on rails 31 on main beam 16 so that it can move longitudinally on the main beam but does not rotate with respect thereto. Drive cylinders 36 can be used to move the gripper assembly longitudinally toward and away from the cutterhead support when the grippers are not engaged with the tunnel wall, and they can be used to move the cutterhead support 12 together with the connected cutterhead 10 and main beam 16 longitudinally with respect to the gripper assembly when the girppers are in engagement with the tunnel wall. Cylinders 36 also serve to limit the pivotal movement of guide 30 and cylinder assemblies 28.

During drilling, the grippers 20 are extended into engagement with the tunnel wall. The drive cylinders 36 are then extended thrusting the cutterhead 10 toward the end face of the tunnel. Simultaneously, the cutterhead 10 is rotated by a motor 38 carried by the cutterhead support 12. The gripper assembly with its grippers 20 engaging the wall of the tunnel provides reaction for both thrust and torque. A plurality of cutting tools, one of which is shown at 40, are mounted on the forward face of the cutterhead 10. The cutting tools 40 cut away the earth formation from the face of the tunnel as the cutterhead is rotated and driven forward. A plurality of buckets 42 are rigidly mounted around the periphery of the cutterhead 12 and rotate therewith. The buckets 42 are disposed so as to scoop up the cuttings as they pass along the invert or floor of the tunnel and drop them into a chute 44 when they reach the top of
the machine. The chute 44 directs the cuttings onto a conveyor 46 which is disposed within the main beam 16 and carries the cuttings to the rear of the machine. The cuttings can then be removed from the tunnel.

When the cutterhead 10 has been advanced a desired distance, the grippers 20 are brought out of engagement with the tunnel wall by retraction of the cylinder assemblies 28. The drive cylinders 36 are then contracted to slide the gripper assembly forward on the main beam 16. The grippers 20 are then re-engaged with the tunnel wall, and drilling begins again.

While the gripper assembly does provide reaction to the torque imposed on the cutterhead support by the rotating cutterhead, there may be, over a period of time, a gradual creeping of the grippers 20 in an accurate path along the tunnel wall due to this torque. Thus, the gripper assembly rolls about the axis A and the main beam and cutterhead support roll with it. It is necessary from time to time to re-align the machine to correct for this roll. In addition, it is necessary to steer the machine both horizontally and vertically to cause the tunnel being drilled to follow the desired path.

In accord with the present invention, a roll correction and steering system is provided on the cutterhead support. The system includes roll correction means and at least part of the roll correction means also serves as steering means.

The roll correction means or roll correction system preferably includes a pair of control shoes 48 which are generally diametrically opposed and located at the sides of the cutterhead support. Each of the shoes 48 has an integral projection 50 extending downwardly therefrom. The projections 50 are arcuate with the axis A as their center. Each of the control shoes 48 is connected to a bottom support assembly comprising a pair of support legs 52, a support shoe 54 mounted at the lower end of each support leg 52, and a hydraulic cylinder assembly 56 interconnecting each support leg 52 with its respective support shoe 54. In particular, each of the control shoes is pivotally connected at the lowermost end of its extension 50 to a respective one of the support legs 52 at respective pivot points 58. A pair of arm structures extend radially outwardly from opposite sides of the cutterhead support 12. Each of these arm structures comprises a vertically disposed front plate 60 and a parallel rear plate 62. Each of the control shoes 48 is partially disposed between the plates 60 and 62 of a respective one of the arm structures so that the arm structures guide the control shoes 48 and restrain their movement to a vertical plane.

Each of the control shoes 48 is connected to the cutterhead support by a respective hydraulic piston and cylinder assembly 64. The piston and cylinder assemblies 64 each have a substantial horizontal component. Thus, since the shoes 48 are disposed at the sides of the cutterhead support 12, they can be reciprocated outwardly and inwardly in a generally radial direction with respect to the cutterhead support 12 for engagement and non-engagement with the walls of the tunnel. The piston and cylinder assemblies 64 are pivoted at their connections to the cutterhead support, i.e., at their radially innermost ends, as well as at their connections to their respective control shoes 48 for pivotal movement in a vertical plane.

Each of the support legs 52 is slidably mounted on a gib 66 on the bottom of the cutterhead support. Each of the legs 52 is movable with respect to the cutterhead support in a plane transverse to axis A and in a path which partially circumscribes the axis A. In this case, the path is a circular arc centered on the axis A, being defined by the gib 66 which is arcuate and centered on axis A. It will be understood that gibs of other forms could be employed to guide the legs 52 in a path which partially circumscribes or compasses the axis A, and also that guiding means other than gibs could be used. For example, the gib could form a circular arc having its center slightly above or below the axis A. In FIG. 6 a modification is shown in which the circular arc gib 66A has its center B located slightly above axis A. The gib could also take non-circular forms. For example, it could be elliptical such as the gib 66B in FIG. 7. In any event the gib is preferably symmetrical about a line perpendicular to the axis A, preferably a vertical line, and has a centroid located on that line near axis A. This provides the balance needed for proper rolling action.

As the legs 52 can be moved relative to the cutterhead support 12, the cutterhead support can similarly be rolled or rotated about the axis A with respect to the legs 52. It will be understood that if the gib 66 is of some form other than a circular arc centered on axis A, the axis A may shift somewhat from its initial position when the machine is being rolled. However, the fact that the centroid of the gib is near axis A ensures that axis A will remain close to the centerline of the tunnel. The pivotal connections of the piston and cylinder assemblies 64 and their substantial horizontal components prevent them from unduly interfering with such rolling action.

In order to roll the machine about the axis A, the control shoes 48 are first extended into firm engagement with the wall of the tunnel. Since the support legs 52 are connected to the control shoes 48, the extension of the control shoes fixes the bottom support assembly with respect to the tunnel floor or invert. Additionally, the weight of the front of the machine on the bottom support assembly tends to hold it firmly in place on the invert of the tunnel and to keep the connected control shoes 48 in place with respect to the tunnel wall. Rolling means are then employed to roll the cutterhead support 12, and thus, the main beam 16, gripper carriage 18, compartments 22 and 24, etc., with respect to the control shoes 48 and support legs 52 about the axis A.

In the embodiment shown in FIGS. 1-3, the rolling means is a pair of hydraulic ram assemblies 68 each having two elements, namely a piston and cylinder. One of the elements of each ram assembly 68 must be connected to a respective one of the control shoes 48 or to the bottom support assembly, and the other element must be connected to the cutterhead support. In the preferred embodiments, one element of each ram assembly 68 is connected to the bottom support assembly as well as to a respective control shoe 48, since each shoe 48 is in turn connected to the bottom support assembly. As shown in FIG. 3, the pistons of the ram assemblies 68 are pivotally connected to the arm structures of the cutterhead support and the cylinders are pivotally connected directly to both the anchor shoes 48 and the support legs 52 at the pivot points 58. It is also necessary that the ram assemblies 68 lie in a vertical plane transverse to the axis A, and that each ram assembly 68 has a non-radial component of direction.

Thus, when the control shoes 48 are in engagement with the wall of the tunnel, the machine can be rolled about the axis A in a desired direction by contacting one of the ram assemblies 68 and extending the other.
Such rolling action will tend to compress one of the piston and cylinder assemblies 64 and tension the other. For this reason, the cylinders of the assemblies 64 can be interconnected so as to maintain a constant overall pressure. This will allow one assembly 64 to contract slightly and the other to expand slightly when the machine rolls, while maintaining the same force on the tunnel wall by the control shoes 48.

After rolling of the machine to re-align it in the tunnel being drilled, the control shoes 48 can be retracted from the tunnel wall by the piston and cylinder assemblies 64 and re-aligned at the sides of the cutterhead support assembly by means of the ram assemblies 68.

It will be appreciated that the gib mounted support legs 52 and attached support shoes 54 guide the cutterhead support during the rolling operation.

In the preferred embodiments shown in the drawings, the roll correction means includes both a bottom support assembly and a pair of control shoes. It will be understood that roll correction could be accomplished in a machine in which the roll correction means per se included a pair of opposed control shoes but not a bottom support assembly or one in which the roll correction means per se included a bottom support assembly but not control shoes. In any event, the roll correction means includes some type of bracing mechanism which can be fixed against the tunnel wall and with respect to which the rolling means can rotate the cutterhead support.

It will be appreciated that since the control shoes 48 are located on opposite sides of the machine, they can be used to horizontally steer the machine. For example, to steer the machine to the right, the control shoe on the right of the machine would be retracted and the control shoe on the left of the machine extended against the tunnel wall, thus shoving the front of the machine to the right. This procedure would be reversed to steer the machine to the left.

As seen in FIG. 1, the support shoes 54 are pivoted to their respective support legs 52 at 70. The lower surface of each of these shoes slopes upwardly near its rear end. Thus, the machine can be steered vertically by extension and contraction of the cylinder assemblies 56. Extension of the cylinder assemblies 56 will lower the front of the machine and contraction will raise the front end of the machine. While in the embodiment shown, the shoes 54 are pivoted to the legs 56 so that only a portion of each shoe 54 moves vertically upon actuation of the cylinder assemblies 56, it will be appreciated that the entire shoe might be made vertically reciprocating with respect to its support leg if desired. Thus, there is incorporated into the roll correction means on the cutterhead support a complete steering system.

It will also be appreciated that when the control shoes 58 are not in engagement with the tunnel wall, the ram assemblies 68 can be used to move the support legs 52 and their respective support shoes 54 and cylinder assemblies 56 in their arcuate path on the gib 66. In particular, contraction of both ram assemblies 68 will move the support legs 52 laterally apart to provide a throughway 72 under the cutterhead support 12 through which workmen can pass to service the cutterhead 10.

Movable support shoes such as 54 and separate vertical steering cylinders such as 56 are necessary only when the gib 66 is in the form of a circular arc centered on the axis A. In other cases, such as when the gib is ellipsoidal as shown in FIG. 7 or when the gib is in the form of a circular arc which is not centered on axis A as shown in FIG. 6, the machine can be designed so that, with the control shoes 48 in retracted position, it can be vertically steered by the ram assemblies 68. For example, in FIG. 6 the gib 66 is in the form of a circular arc with its center located above axis A at B. The machine can be steered upwardly by extending both of the ram assemblies 68, sliding support legs 52 toward each other, and downwardly by contracting both of the ram assemblies 68. In the embodiment of FIG. 7, the gib 66' is elliptical, having its centroid at A. The machine can be steered downwardly by extending both ram assemblies 68 and upwardly by contracting both ram assemblies 68.

Referring now to FIGS. 4 and 5, another embodiment of the invention is shown. The tunnel boring machine of FIGS. 4 and 5 is basically the same as that of FIGS. 1–3. Briefly, the machine of FIGS. 4 and 5 comprises a cutterhead 10, having cutting tools 40 and buckets 42, and rotatably mounted on a cutterhead support 12'. A main beam 16 extends rearwardly from the cutterhead support 12' and a gripper assembly including a carriage 18 and grippers 20 is mounted on the main beam 16. Compartments (not shown) would be carried by the main beam 16. The machine also includes drive cylinders 36 and motor 38.

The cutterhead support 12' has arm structures comprising front plates 60' and rear plates 62' essentially the same as the arm structures of the embodiment of FIGS. 1–3. Disposed partially between each pair of plates 60' and 62' is a control shoe 48' with an arcuate downward projection 50'. The projections 50' are pivotally connected at points 58' to a bottom support assembly which, in this embodiment, is a unitary support member 74. The support member 74 includes two upstanding, upwardly open guides 80 with an opening 78 therebetween to provide a throughway under the cutterhead support 12' to the cutterhead 10. Disposed in the guides 80 are a pair of integral downward projections 76 of the cutterhead support 12'. As viewed in the transverse vertical plane of FIG. 5, there is clearance between the inner surfaces of the guides 80 and the projections 76 on all sides. Thus, the projections 76 can move both sideways and vertically with respect to the support member 74. This allows the support member 74 to be moved in a plane transverse to axis A in a path which partially circumscribes the axis A, and also allows the cutterhead support 12' to be rolled generally about axis A relative to support member 74. In this embodiment there is no gib or the like to guide the support member 74 in a distinct path. However, it can be seen that, due to the clearance between the guides 80 and the projections 76, the support member 74 can move in a path having one component of direction extending horizontally toward one side of the machine and another component extending vertically upward along that side. Similarly, support member 74 can move toward the other side of the machine and upwardly therealong. Such a path partially circumscribes the axis A. The contact between the lower surface of the support member 74 and the invert of the tunnel helps to guide the support member 74 in its movement, particularly when the support member 74 is curved to correspond to the curvature of the tunnel as shown. As viewed in the longitudinal vertical plane of FIG. 4, the projections 76 fit tightly within the guides 80 from front to back whereby relative forward and backward movement between the support member 74 and the cutter-
head support is prevented. If opening 78 is not desired, a single upwardly open guide and mating projection of the cutterhead may be provided. The control shoes 48 are radially extendible and retractable with respect to the cutterhead support 12 by means of the piston and cylinder assemblies 64 on which the shoes 48 are mounted. Like the assemblies 64 of the first embodiment, the assemblies 64' are pivoted at both ends for pivoting in a vertical plane transverse to the axis A. The piston and cylinder assemblies 64' are disposed in a truly radial direction and, when the machine is properly aligned in the tunnel, lie between the plates 60' and 62' of their respective arm structures. Because of the purpose of the assemblies 64' is to effect radial movement of the control shoes 48', their truly radial position makes them more efficient than the cylinders 64 of the embodiment of FIGS. 1-3. However, the assemblies 64 of FIGS. 1-3 would be easier to service, since they do not lie between the plates 60 and 62. It will be appreciated that either of these piston and cylinder arrangements, i.e., either assemblies such as 64 or assemblies such as 64', as well any other suitable arrangements could be used with either embodiment of the invention depending on the requirements of the particular machine.

Rolling means are provided in the form of a pair of hydraulic ram assemblies 68' similar to the ram assemblies 68 of FIGS. 1-3. Ram assemblies 68' each have one element, i.e., the piston, connected to a respective one of the arm structures of the cutterhead support and the other element, i.e., the cylinder, connected to support member 74 and a respective one of the control shoes 48' at one of the connection points 58' on the same side of the machine as the respective arm structure. Ram assemblies 68' lie in a transverse vertical plane and each has a non-radial component of direction so that they can effect the rolling action. As with the embodiment of FIGS. 1-3, the machine of FIGS. 4 and 5 can be steered horizontally by means of the control shoes 48'. To steer to the right, the right hand control shoe is retracted and the left hand control shoe extended against the tunnel wall. The procedure is reversed to steer to the left.

Because of the unitary construction of the bottom support assembly in the form of support member 74, the machine can be steered vertically by means of the ram assemblies 68. To steer the machine upwardly, both ram assemblies 68 are extended moving the cutterhead support 12' upwardly with respect to support member 74. To steer downwardly, both ram assemblies 68' are contracted so that the cutterhead support 12' is lowered with respect to support member 74. Finally, the machine can be rolled about axis A in much the same manner as the machine of FIGS. 1-3 by retracting one of the ram assemblies 68' and extending the other. Axis A may shift somewhat during rolling but will remain close to the centerline of the tunnel.

Thus, both embodiments of the invention provide a roll correction system on the cutterhead support of a tunnel boring machine. The roll correction system also incorporates vertical and horizontal steering means so that a complete steering and alignment system is provided on the cutterhead support.

It will be apparent to those skilled in the art that many modifications of the invention are possible, the scope of the invention being limited only by the claims. We claim:

1. A tunnel boring machine for progressively drilling a tunnel while passing therethrough and comprising:
   a cutterhead support;
   a cutterhead rotatably mounted on a forward end of said cutterhead support for rotation about an axis generally coincident with a longitudinal centerline of said tunnel;
   a frame assembly rigidly connected to said cutterhead support and extending generally rearwardly therefrom;
   a gripper assembly mounted on said frame assembly rearwardly of said cutterhead support for longitudinal movement with respect to said cutterhead support, said gripper assembly comprising a pair of oppositely directed grippers selectively radially extensible and retractable for engagement and non-engagement with the wall of said tunnel; drive means interconnecting said cutterhead support and said gripper assembly and operative to cause relative longitudinal movement of said cutterhead support and said gripper assembly; a bottom support assembly mounted on a lower portion of said cutterhead support, extending from said cutterhead support to the invert of said tunnel, and operative to support the weight of said cutterhead support and said cutterhead on the invert of said tunnel during each operational mode of said tunnel boring machine including a drilling mode in which said grippers are engaged with the wall of said tunnel and said cutterhead support is driven longitudinally with respect to said gripper assembly by said drive means; and roll correction means carried by said cutterhead support and operative to rotate said cutterhead support generally about the axis of said cutterhead.

2. A tunnel boring machine according to claim 1 wherein said roll correction means includes bracing means fixable against the wall of said tunnel, and rolling means interconnecting said bracing means with said cutterhead support and operative to rotate said cutterhead support with respect to said bracing means about the axis of said cutterhead when said bracing means is fixed against the wall of said tunnel.

3. A tunnel boring machine according to claim 2 wherein said bracing means comprises a pair of oppositely directed control shoes each selectively extensible and retractable in a generally radial direction with respect to said cutterhead support for engagement and non-engagement with the wall of said tunnel, said rolling means interconnecting each of said control shoes with said cutterhead support.

4. A tunnel boring machine according to claim 3 wherein said control shoes are located on opposite sides of said tunnel boring machine whereby said control shoes are operative to horizontally steer said tunnel boring machine.

5. A tunnel boring machine according to claim 3 wherein said roll correction means further includes a pair of piston and cylinder assemblies, each of said control shoes being mounted on a respective one of said piston and cylinder assemblies and each of said piston and cylinder assemblies having a radially innermost end pivotally connected to said cutterhead support assembly for pivoting in a plane transverse to the axis of said cutterhead, and wherein said rolling means is a pair of ram assemblies each lying generally in a plane transverse to the axis of said cutterhead and being disposed in a direction having a non-radial component,
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and each of said ram assemblies having a first element connected to a respective one of said anchor shoes and a second element, telescopic with said first element, connected to said cutterhead support.

6. A tunnel boring machine according to claim 4 wherein said roll correction means further comprises said bottom support assembly.

7. A tunnel boring machine according to claim 6 wherein said bottom support assembly is movably with respect to said cutterhead support in a plane transverse to the axis of said cutterhead in a path which partially circumscribes the axis of said cutterhead, and said bottom support assembly is connected to each of said control shoes.

8. A tunnel boring machine according to claim 7 wherein said control shoes are located on opposite sides of said tunnel boring machine and each of said control shoes has an integral projection extending downwardly therefrom and pivotally connected to said bottom support assembly wherein said cutterhead support includes a pair of arm structures extending laterally outwardly on opposite sides of said cutterhead support, and wherein said second element of each of said ram assemblies is directly connected to a respective one of said arm structures on the said side of said tunnel boring machine as the respective one of said control shoes.

9. A tunnel boring machine according to claim 7 wherein said bottom support assembly is operative to vertically steer said tunnel boring machine.

10. A tunnel boring machine according to claim 9 wherein said control shoes are located on opposite sides of said tunnel boring machine whereby said control shoes are operative to horizontally steer said tunnel boring machine.

11. A tunnel boring machine according to claim 2 wherein said bracing means comprises said bottom support assembly.

12. A tunnel boring machine for progressively drilling a tunnel while passing therethrough and comprising:

a cutterhead support;

a cutterhead rotatably mounted on a forward end of said cutterhead support for rotation about an axis generally coincident with a longitudinal centerline of said tunnel;

a frame assembly rigidly connected to said cutterhead support and extending generally rearwardly therefrom;

a gripper assembly mounted on said frame assembly rearwardly of said cutterhead support for longitudinal movement with respect to said cutterhead support, said gripper assembly comprising a pair of oppositely directed grippers selectively radially extensible and retractable for engagement and non-engagement with the wall of said tunnel;

drive means interconnecting said cutterhead support and said gripper assembly and operative to cause relative longitudinal movement of said cutterhead support and said gripper assembly; and

roll correction means carried by said cutterhead support and operative to rotate said cutterhead support generally about the axis of said cutterhead including bracing means fixable against the wall of said tunnel and rolling means interconnecting said bracing means with said cutterhead support and operative to rotate said cutterhead support with respect to said bracing means about the axis of said cutterhead when said bracing means is fixed against the wall of said tunnel, wherein said bracing means comprises a bottom support assembly mounted on a lower portion of said cutterhead support and extending from said cutterhead support to the invert of said tunnel and movable with respect to said cutterhead support in a plane transverse to the axis of said cutterhead in a path which partially circumscribes the axis of said cutterhead, and wherein said rolling means is a pair of ram assemblies each lying generally in a plane transverse to the axis of said cutterhead and being disposed in a direction having a non-radial component, and each of said ram assemblies having a first element connected to said bottom support assembly and a second element, telescopic with said first element, connected to said cutterhead support, said ram assemblies being operative to move said bottom support assembly in said path.

13. A tunnel boring machine according to claim 12 wherein said bottom support assembly is slidably mounted on guiding means rigidly connected to said cutterhead support for movement in said path.

14. A tunnel boring machine according to claim 13 wherein said bottom support assembly comprises a pair of support legs each depending generally downwardly from said cutterhead support and independently movable in said path.

15. A tunnel boring machine according to claim 14 wherein said guiding means is arcuate in configuration and has a center vertically displaced from the axis of said cutterhead whereby said tunnel boring machine can be vertically steered by moving said support legs toward and away from each other in said path.

16. A tunnel boring machine according to claim 14 wherein said guiding means is generally elliptical in configuration and is symmetrical about a vertical line through the axis of said cutterhead whereby said tunnel boring machine can be vertically steered by moving said support legs toward and away from each other in said path.

17. A tunnel boring machine according to claim 14 wherein said bottom support assembly further includes a pair of support shoes each mounted at a lowermost end of a respective one of said support legs and means on each of said support legs for moving at least a portion of the respective support shoe vertically upwardly and downwardly with respect to said support leg to thereby vertically steer said tunnel boring machine.

18. A tunnel boring machine according to claim 12 wherein said bottom support assembly is a unitary support member.

19. A tunnel boring machine according to claim 18 wherein said bottom support assembly has an opening therein forming a throughway under said cutterhead support.

20. A tunnel boring machine according to claim 12 wherein said bottom support assembly is vertically movable with respect to said cutterhead support and wherein said ram assemblies are operative to cause respective vertical movement between said cutterhead support and said bottom support assembly and thus to vertically steer said tunnel boring machine.

21. A tunnel boring machine according to claim 20 wherein said bottom support assembly includes an upwardly open guide having a front inner surface, a rear inner surface, and opposed side inner surfaces, and said cutterhead support includes a downward projection
disposed in said guide.

22. A tunnel boring machine according to claim 21 wherein said projection fits tightly between said front inner surface and said rear inner surface and fits loosely between said side inner surfaces.