

DESCRIPTION

Title of Invention

ROCK BOLT

5 Technical Field

[0001] The present invention relates to a rock bolt.

Background Art

[0002] In this technical field, a rock bolt disclosed in Patent Literature 1 is known. The rock bolt includes a plurality of anchors and a stem
10 provided between the anchors. This stem can cope with a static load caused by slow deformation of ground and a dynamic load caused by a crack generated in the ground.

Citation List

Patent Literature

15 [0003] Patent Literature 1: Japanese Unexamined Patent Publication No. 2010-513763

Summary of Invention

Technical Problem

[0004] A tunnel construction includes steps of providing a plurality of
20 holes in a direction from the center of the tunnel to the inside of the ground and embedding a rock bolt into the hole. The embedded rock bolt extends with the deformation of the ground in the vicinity of the rock bolt to generate stress. This stress counters a released ground pressure.

25 [0005] For example, it is desirable to use a high-rigid rock bolt at a position in which a high ground pressure is expected to occur.

However, the ground pressure may become smaller than expected depending on the environment around a drilling area. In this case, it is uneconomical in that the rock bolt has excessive strength. Further, when an original ground pressure is excessively large, the magnitude of the ground pressure exceeds the strength of the rock bolt and the rock bolt cannot counter the ground pressure. In this case, a property in which the ground pressure decreases when the ground is deformed is used. Specifically, the ground pressure is decreased to a certain extent by allowing a predetermined deformation amount of the ground. Accordingly, the rock bolt counters the decreased ground pressure.

[0006] These measures are effective when the magnitude of the ground pressure or the relationship between the deformation amount of the ground and the ground pressure is within a predicted range. That is, the rock bolt is designed to cope with predicted ground characteristics.

However, the ground characteristics are various depending on the overburden height and the environment around the excavation area. For this reason, in the field of the art, a rock bolt capable of coping with a wide range of ground characteristics has been desired.

Solution to Problem

[0007] An aspect of the invention is a rock bolt which is embedded in a hole provided in ground, including: a first member that is a rod body extending in a predetermined direction and is disposed inside the hole; and a slide regulation mechanism which disturbs a movement of the first member in accordance with deformation of the ground, wherein the slide regulation mechanism includes: a first regulation portion which is fixed to the first member, and a second regulation portion which is

separated from the first member by a predetermined distance between the first regulation portion and an opening of the hole and contacts the first regulation portion when the first member moves in accordance with the deformation of the ground.

5 [0008] When the ground having the rock bolt embedded therein is deformed, the first member has a mode of moving in accordance with the deformation of the ground and a mode of disturbing the movement by the slide regulation mechanism. According to these modes, the rock bolt can provide different resistance forces respectively
10 corresponding to the modes to the ground. Thus, it is possible to cope with a wide range of ground characteristics.

[0009] Further, the rock bolt according to an aspect of the invention may further include: a second member that is a rod body extending in the predetermined direction and is provided in parallel to the first
15 member inside the hole; a slide connection mechanism which connects one of the first member and the second member to the other thereof to be relatively movable; and a slide control mechanism which generates a force in a direction opposite to a movement direction when one of the first member and the second member moves with respect to the other
20 thereof. The first member may include a first extension portion which is elastically deformable. The slide regulation mechanism may regulate a range in which one of the first member and the second member is movable with respect to the other thereof. The stiffness of the first extension portion may be larger than the stiffness of the slide
25 control mechanism.

[0010] Since the rock bolt includes the slide connection mechanism, it

is possible to relatively move one of the first member and the second member with respect to the other thereof. Then, during this movement, the slide control mechanism generates a resistance force with respect to the movement. Further, the maximal movement positions of the first member and the second member are defined by the slide regulation mechanism. When the ground having the rock bolt embedded therein is deformed, the rock bolt first copes with the deformation of the ground while generating the resistance force by the movement of the first member and the second member using the slide control mechanism. According to the resistance force, it is possible to counter a relatively small ground pressure. Thus, the rock bolt can support the ground generating a relatively small ground pressure. Then, after the first member and the second member reach the maximal movement positions, the deformation of the ground is handled by the extension of the extension portion of the first member. According to the extension of the extension portion, stress is generated. According to the stress, it is possible to counter a relatively large ground pressure. Thus, the rock bolt can support the ground generating a relatively large ground pressure. Here, the stiffness of the extension portion of the first member is higher than the stiffness of the slide control mechanism. For this reason, when the deformation of the ground occurs, the movement of the slide connection mechanism occurs and then the extension of the first extension portion occurs. Thus, the rock bolt can support the ground generating a relatively small ground pressure and the ground generating a relatively large ground pressure. Thus, the rock bolt can cope with a wide range of ground characteristics.

[0011] The slide connection mechanism may connect one end of the first member and one end of the second member to each other, the slide regulation mechanism may define a maximum length from the other end of the first member to the other end of the second member, and the first member may include a first anchor portion which is provided at the other end side in relation to the first extension portion and maintains a relative position with respect to the ground. According to the slide regulation portion, it is possible to control the state of supporting the ground using the resistance force generated by the slide control mechanism to a desired state. Further, according to these anchor portions, it is possible to control the state of supporting the ground using the stress generated in the first member and the second member to a desired state.

[0012] The rock bolt may further include a fixing mechanism which is attached to the other end side in relation to the first anchor portion and maintains a relative position with respect to the ground and the first member may further include a second extension portion which is provided between the other end and the first anchor portion. According to this configuration, the fixing mechanism is caught by the opening of the hole. For this reason, the other end of the first member to which the fixing mechanism is attached serves as an anchor. Thus, since the second extension portion extends, a region corresponding to the deformation of the ground can extend.

[0013] The slide control mechanism may be a compression spring. A relationship between the deformation amount of the compression spring and the force can be easily obtained. Thus, it is possible to easily set a

force in a direction opposite to the movement direction of the rod body.

[0014] A cross-sectional area of the first anchor portion may be larger than a cross-sectional area of the first extension portion. According to this configuration, the anchor portion protrudes from the first extension portion toward the ground. Since the protruding portion serves as a resistance in the movement direction of the first member, it is possible to appropriately maintain the relative position of the anchor portion with respect to the ground.

[0015] Further, the first regulation portion may include a first contact portion which contacts the second regulation portion of the slide regulation mechanism. The second regulation portion may include an insertion portion through which the first member is inserted and a second contact portion which is provided to surround the insertion portion and with which the first contact portion comes into press-contact. The rock bolt can provide a first resistance force generated in the mode until the first contact portion contacts the second contact portion to the ground. Furthermore, the rock bolt can provide a second resistance force generated in the mode after the first contact portion contacts the second contact portion to the ground. Since the slide regulation mechanism disturbs the movement of the first member after the first contact portion contacts the second contact portion, the second resistance force is larger than the first resistance force. Thus, the rock bolt can support the ground generating a relatively small ground pressure by the first resistance force. Further, the rock bolt can support the ground generating a relatively large ground pressure by the second resistance force. Thus, the rock bolt can cope with a wide

range of ground characteristics.

5 [0016] The slide regulation mechanism may further include a distance regulation portion which regulates a maximum distance between the first regulation portion and the second regulation portion. The switching timing from the first resistance force to the second resistance force can be controlled by the distance between the first regulation portion and the second regulation portion. Thus, since the distance regulation portion is provided, the slide regulation mechanism can control the switching timing from the first resistance force to the second resistance force. Thus, the rock bolt can generate the resistance force suitable for supporting the ground.

10 [0017] The distance regulation portion may be a flexible member of which one end is fixed to the first regulation portion and the other end is fixed to the second regulation portion and which has a length corresponding to the maximum distance. According to this configuration, the second regulation portion is not separated from the first regulation portion by the length or more of the flexible member. Thus, it is possible to suppress a distance from the first regulation portion to the second regulation portion from becoming a maximum distance or more.

20 [0018] The distance regulation portion may be a protrusion portion which is provided at a position separated from the first regulation portion in the extension direction of the first member by a distance corresponding to the maximum distance. According to this configuration, the second regulation portion is not separated from the first regulation portion beyond the position of the protrusion portion.

Thus, it is possible to suppress a distance from the first regulation portion to the second regulation portion from becoming a maximum distance or more.

[0019] The first regulation portion may include an attachment surface which extends in the predetermined direction and to which a fixing material filled in the hole is attached. The attachment surface may be provided with a ridge portion protruding from the attachment surface. According to this configuration, it is possible to strongly attach the first regulation portion and the fixing material to each other.

Advantageous Effects of Invention

[0020] According to the rock bolt of the invention, it is possible to cope with a wide range of ground characteristics.

Brief Description of Drawings

[0021] FIG. 1 is a diagram showing a cross-section of a tunnel to which a rock bolt according to this embodiment is applied.

FIG. 2 is a cross-sectional view showing a structure of the rock bolt according to this embodiment.

FIG. 3 is a cross-sectional view showing an operation of the rock bolt shown in FIG. 2.

FIG. 4 is a graph showing a support function of the rock bolt.

FIG. 5 is a cross-sectional view showing a rock bolt according to a modified example.

FIG. 6 is a cross-sectional view showing a rock bolt according to Comparative Example 1.

FIG. 7 is a cross-sectional view showing a rock bolt according to a reference example.

FIG. 8 is a cross-sectional view showing a structure of a rock bolt according to a second embodiment.

FIG. 9 is a cross-sectional view showing a structure of a rock bolt according to a comparative example.

5 FIG. 10 is a graph showing characteristics of the rock bolts shown in FIGS. 8 and 9.

FIG. 11 is a diagram showing an operation of the rock bolt shown in FIG. 8.

10 FIG. 12 is a cross-sectional view showing a modified example of the rock bolt according to the second embodiment.

FIGS. 13(a) and 13(b) are perspective views showing a modified example of a ring shown in FIG. 8.

FIG. 14 is a diagram showing a structure of the rock bolt according to a modified example.

15 **Description of Embodiments**

[0022] Hereinafter, embodiments of the invention will be described in detail with reference to the accompanying drawings. In the description of the drawings, the same components will be denoted by the same reference numerals and a repetitive description thereof will be omitted.

20 [0023] As shown in FIG. 1, a rock bolt 1 is used for tunnel construction using a so-called New Austrian Tunneling Method (NATM). In the tunnel construction using NATM, ground 101 is excavated. Next, a concrete wall 102 is provided. Next, a hole 103 is provided to extend from the concrete wall 102 to the ground 101. Then, the rock bolt 1 is
25 embedded in the hole 103.

[0024] As shown in FIG. 2, the rock bolt 1 is embedded in a fixing

material 104 filled in the hole 103. The fixing material 104 is, for example, mortar or resin.

5 [0025] The rock bolt 1 includes a fixed side rod body (a second member) 2, a movable side rod body (a first member) 3, a fixing mechanism 4, and a connection mechanism (a slide connection mechanism) 6.

10 [0026] The fixed side rod body 2 is provided in a bottom 103b in parallel to the movable side rod body 3. The fixed side rod body 2 is a columnar rod body. The fixed side rod body 2 extends from the bottom 103b toward an opening 103a. A high-tensile steel rod having relatively high stiffness is used in the fixed side rod body 2. One end of the fixed side rod body 2 is fixed to a connection mechanism 6. The other end of the fixed side rod body 2 is embedded in the fixing material 104.

15 [0027] The fixed side rod body 2 further includes two fixed side anchors 7 and 8, a fixed side shaft portion 9, and a fixed side extension portion 11. When the ground 101 is deformed, the relative positions of the fixed side anchors 7 and 8 with respect to the ground 101 are maintained. A case capable of maintaining the position with respect to
20 the ground 101 means a case in which the movement amount of the fixed side anchors 7 and 8 with the deformation of the ground 101 is smaller than the extension of the fixed side shaft portion 9. According to this configuration, the deformation of the ground 101 acts on the fixed side extension portion 11. The shapes of the fixed side anchors 7
25 and 8 are not particularly limited as long as the shape can maintain the position with respect to the ground 101. For example, the fixed side

anchors 7 and 8 may have disc shapes each having a cross-sectional area larger than the cross-sectional area of the fixed side shaft portion 9. In other words, the outer diameters of the fixed side anchors 7 and 8 are larger than the outer diameter of the fixed side shaft portion 9. The fixed side anchor 7 is disposed in the vicinity of one end of the fixed side shaft portion 9. The fixed side anchor 8 is disposed in the vicinity of the other end of the fixed side shaft portion 9. The fixed side extension portion 11 is provided between the fixed side anchors 7 and 8. The fixed side extension portion 11 is elastically deformable with the deformation of the ground 101. The fixed side extension portion 11 has stiffness based on the diameter of the fixed side shaft portion 9 and the Young's modulus of the steel material.

[0028] The movable side rod body 3 is disposed on the side of an opening 103a of the hole 103. The movable side rod body 3 is a columnar rod body. The movable side rod body 3 extends to protrude from the hole 103. A high-tensile steel rod having relatively high stiffness is used in the movable side shaft portion 12 similarly to the fixed side rod body 2. One end of the movable side rod body 3 is connected to the connection mechanism 6. The other end of the movable side rod body 3 protrudes from the opening 103a. The fixing mechanism 4 is attached to the other end of the movable side rod body 3.

[0029] The movable side rod body 3 includes a movable side shaft portion 12, movable side anchors 13 and 14, a piston 15 (a first regulation portion), and movable side extension portions 16, 17, and 18. The movable side anchors 13 and 14 have the same function and

configuration as those of the fixed side anchors 7 and 8 of the fixed side rod body 2. The movable side anchor (the first anchor portion) 13 is attached to the vicinity of the other end of the movable side shaft portion 12. The movable side anchor 14 is attached between the movable side anchor 13 and the piston 15. The piston 15 has a disc shape. The piston 15 is fixed to one end of the movable side shaft portion 12. The outer diameter of the piston 15 is larger than the outer diameter of the movable side shaft portion 12. The movable side extension portions 16, 17, and 18 are elastically deformable with the deformation of the ground 101 similarly to the fixed side extension portion 11. The movable side extension portions 16, 17, and 18 have stiffness based on the diameter of the movable side shaft portion 12 and the Young's modulus of the steel material. The movable side extension portion (the first extension portion) 16 is provided between the movable side anchors 13 and 14. The movable side extension portion (the second extension portion) 17 is provided between the movable side anchor 13 and the fixing mechanism 4 at the other end side in relation to the movable side anchor 13. The movable side extension portion 18 is provided between the movable side anchor 14 and the piston 15 at one end side in relation to the movable side anchor 13.

[0030] The fixing mechanism 4 maintains the relative position of the other end of the movable side rod body 3 with respect to the ground 101. The fixing mechanism 4 includes a washer 19 and a bolt 21. The washer 19 is a disc-shaped or rectangular plate member. The area of the washer 19 is larger than the opening area of the opening 103a. A through-hole is provided at the center portion of the washer 19. The

other end side of the movable side rod body 3 is inserted through the hole 103. The bolt 21 is attached to a male screw portion provided at the other end side of the movable side rod body 3. The bolt 21 causes a force of pressing the washer 19 against the ground 101.

5 [0031] The connection mechanism 6 includes a cylindrical cylinder casing (a slide connection mechanism) 22. In the positional relationship between the fixed side rod body 2 and the movable side rod body 3, the cylinder casing 22 connects one of them to the other thereof to be relatively movable. In the positional relationship between the
10 fixed side rod body 2 and the movable side rod body 3, the cylinder casing 22 defines a range in which one of them is relatively movable with respect to the other thereof.

[0032] The fixed side rod body 2 is fixed to one end wall 22a of the cylinder casing 22. One end wall 22a faces the bottom 103b of the
15 hole 103. The piston 15 is accommodated inside the cylinder casing 22. The other end wall 22b (the second regulation portion) of the cylinder casing 22 includes a through-hole 22c. The movable side extension portion 18 is inserted through the through-hole 22c. The center axis line of the through-hole 22c overlaps the center axis line of
20 the cylinder casing 22. The inner diameter of the through-hole 22c is slightly larger than the outer diameter of the movable side shaft portion 12. The inner diameter of the cylinder casing 22 is slightly larger than the outer diameter of the piston 15. In short, the movable side rod body 3 may slide with respect to the cylinder casing 22. The piston 15
25 and the other end wall 22b constitute a slide regulation mechanism 23. The slide regulation mechanism 23 regulates the movable range of the

movable side rod body 3 with respect to the fixed side rod body 2.

[0033] The cylinder casing 22 accommodates a plurality of compression springs (slide control mechanisms) 24. When one of the fixed side rod body 2 and the movable side rod body 3 moves with respect to the other thereof, the compression spring 24 generates a force in a direction opposite to the movement direction. The compression spring 24 is disposed between the piston 15 and the other end wall 22b.

[0034] Next, the operation of the rock bolt 1 when the ground 101 is deformed will be described.

[0035] FIG. 3(a) shows the rock bolt 1 in an initial state. In the initial state, the piston 15 of the movable side rod body 3 is pressed against one end wall 22a of the cylinder casing 22 by the compression spring 24. The entire length of the rock bolt 1 is a length L1 from the other end of the fixed side rod body 2 to the other end of the movable side rod body 3. Thus, the length L1 of the rock bolt 1 in the initial state is the shortest. In the rock bolt 1 in the initial state, a position maintained with respect to the ground 101 indicates a portion 12a to which the fixing mechanism 4 is attached, the movable side anchors 13 and 14, and the fixed side anchors 7 and 8. Thus, the rock bolt 1 in the initial state has three regions capable of following the deformation of the ground 101 when the ground 101 is deformed along a movement direction A1. Three regions include a first region R1, a second region R2, and a third region R3. The first region R1 is a region between the portion 12a and the movable side anchor 13. The second region R2 is a region between the movable side anchor 13 and the fixed side anchor 7. The third region R3 is a region between the fixed side anchors 7

and 8.

[0036] The first region R1 is provided with the movable side extension portion 17. The third region R3 is provided with the fixed side extension portion 11. Thus, the first region R1 and the third region R3 cope with the deformation of the ground 101 while extending on the basis of the stiffness of the movable side extension portion 17 and the fixed side extension portion 11. Meanwhile, the second region R2 is provided with the connection mechanism 6. Thus, the second region R2 copes with the deformation of the ground 101 while the movable side rod body 3 moves on the basis of the stiffness of the compression spring 24 accommodated in the connection mechanism 6. Here, the stiffness of the movable side extension portion 17 and the fixed side extension portion 11 is larger than the stiffness of the compression spring 24. In other words, the stiffness of the compression spring 24 is smaller than the stiffness of the movable side extension portion 17 and the fixed side extension portion 11. According to the relationship of the stiffness, the second region R2 extends before the first region R1 and the third region R3 extend when the ground 101 is deformed.

[0037] FIG. 3(b) shows the rock bolt 1 when the extension of the second region R2 becomes maximal. When the initial state shown in FIG. 3(a) changes to the state shown in FIG. 3(b), the piston 15 gradually moves toward the opening 103a. Thus, the compression spring 24 contracts. A force generated in a direction A2 opposite to the movement direction A1 of the piston 15 due to the contraction of the compression spring 24 is applied to the piston 15. The force acting on the piston 15 is transmitted to the movable side anchors 13 and 14 and

the portion 12a through the movable side shaft portion 12 so that the deformation of the ground 101 is disturbed.

[0038] Then, when the compression spring 24 is compressed to the minimum length as shown in FIG. 3(b), the piston 15 cannot move toward the opening 103a. A state from the initial state until the movement of the piston 15 is regulated will be referred to as a first state and a state after the movement is regulated will be referred to as a second state. In the second state, the movement of the movable side rod body 3 toward the movement direction A1 is regulated. Thus, the rock bolt 1 in the second state has five regions capable of following the deformation of the ground 101. Five regions indicate a fourth region R4, a fifth region R5, and a sixth region R6 in addition to the first region R1 and the third region R3. The fourth region R4 is a region between the movable side anchors 13 and 14. The fifth region R5 is a region between the movable side anchor 14 and the piston 15. The sixth region R6 is a region between the cylinder casing 22 and the fixed side anchor 7.

[0039] For example, as shown in FIG. 3(c), when a part 101b of the ground 101 corresponding to the third region R3 is deformed, a force is applied to the fixed side extension portion 11 so that the fixed side extension portion 11 between the fixed side anchors 7 and 8 extends. At this time, the fixed side rod body 2 extends on the basis of the magnitude of the applied force and the stiffness of the fixed side extension portion 11. Similarly, for example, when a part 101c of the ground 101 corresponding to the fourth region R4 is deformed, a force is applied to the movable side rod body 3 so that the movable side

extension portion 16 extends. At this time, the movable side rod body 3 extends on the basis of the magnitude of the applied force and the stiffness of the movable side extension portion 16.

[0040] The operational effect of the rock bolt 1 will be described while comparing with a rock bolt according to a comparative example.

[0041] First, ground characteristics regarding ground deformation induced by ground excavation will be described. FIG. 4 is a graph showing a ground reaction curve showing ground characteristics. A horizontal axis indicates displacement. A vertical axis indicates stress. The stress is also referred to as a ground pressure. The ground reaction curves G1 to G6 respectively indicate a relationship between the ground pressure and the displacement of the ground having different ground characteristics. A relationship between the ground reaction curves G1 to G6 and the ground characteristics is as below. The overburden height indicates the thickness of the ground from the upper end of the tunnel to the ground surface. The rock mass classification is one of indexes showing the behavior of the ground. Additionally, in the following description, it is assumed that the ground 101 has ground characteristics indicated by the ground reaction curve G4.

Ground reaction curve G1 ... Overburden height: low, Rock mass classification: slightly hard.

Ground reaction curve G2 ... Overburden height: middle, Rock mass classification: slightly hard.

Ground reaction curve G3 ... Overburden height: high, Rock mass classification: slightly hard.

Ground reaction curve G4 ... Overburden height: low, Rock

mass classification: slightly soft.

Ground reaction curve G5 ... Overburden height: middle, Rock mass classification: slightly soft.

5 Ground reaction curve G6 ... Overburden height: high, Rock mass classification: slightly soft.

[0042] When the ground reaction curves G1, G2, and G3 are compared with one another, it is understood that the ground pressure becomes higher as the overburden height becomes higher. Referring to the ground reaction curve G1 (Overburden height: low, Rock mass classification: slightly hard), it is understood that the ground pressure becomes lower as the displacement becomes larger. This tendency is also the same in other ground reaction curves G2, G3, G4, G5, and G6. Further, when the ground reaction curve G1 (Overburden height: low, Rock mass classification: slightly hard) and the ground reaction curve G4 (Overburden height: low, Rock mass classification: slightly soft) having the same overburden height are compared with each other, the inclination of the ground reaction curve G4 is looser than the inclination of the ground reaction curve G1. In other words, it is understood that the inclination becomes looser as the rock mass classification index becomes lower. Then, the ground causes elastic deformation when the displacement is small, but causes plastic deformation when the displacement (or damage) is large. Points P1 to P6 respectively shown in the ground reaction curves G1 to G6 show limited values relating to the elastic deformation of the ground. For example, when the displacement of the ground having the ground reaction curve G1 (Overburden height: low, Rock mass classification: slightly hard)

becomes larger than the displacement shown in the point P1, plastic deformation occurs. In addition, these ground characteristics are general trends and a relationship between overburden height and ground pressure is various due to plate motions and faults. Further, the ground property values are not uniform in one region. Thus, it is difficult to recognize these ground characteristics with high accuracy.

[0043] First, a rock bolt according to a comparative example will be described. FIG. 6 shows a rock bolt 201 according to Comparative Example 1. As shown in FIG. 6(a), Comparative Example 1 relates to a so-called full fixing type rock bolt 201. The rock bolt 201 includes a male screw-shaped unevenness (not shown) provided in an outer peripheral surface of a core material 202. Since the fixing material 104 which is mortar enters the unevenness, a relative position of a portion embedded in the fixing material 104 in the rock bolt 201 with respect to the ground 101 is maintained.

[0044] A bolt characteristic diagram G11 of FIG. 4 shows a relationship between the displacement of the rock bolt 201 and stress generated in the rock bolt 201. When the ground 101 is deformed, the full fixing type rock bolt 201 extends in response to the deformation of the ground 101 (see the extension $\Delta S3$ of FIG. 6(b)). Stress is generated in the rock bolt 201 by the extension. When the extension of the rock bolt 201 increases as indicated by the bolt characteristic diagram G11, the stress increases in proportion to the extension. When the extension of the rock bolt 201 exceeds the yield point of the steel material (see the point P8 of the bolt characteristic diagram G11), the rock bolt 201 is plastically deformed to be eventually broken (see the extension $\Delta S4$ and

the point P9 of the bolt characteristic diagram G11 in FIG. 6(c)).

[0045] Here, the ground characteristic of the ground 101 is the ground reaction curve G4 (Soil covering height: low, Rock mass classification: slightly soft). A state in which the ground 101 is supported by the rock bolt 201 is indicated by the intersection point P7 between the bolt characteristic diagram G11 and the ground reaction curve G4. The rock bolt 201 exhibits high pull-out strength since the relative position of the core material 202 embedded in the fixing material 104 with respect to the ground 101 is maintained. For example, also in other grounds (see the ground reaction curves G2, G3, and G5) causing a higher ground pressure than that of the ground 101, the bolt characteristic diagram G11 has intersection points with the ground reaction curves G2, G3, and G5. Thus, it is possible to improve the ground deformation suppressing effect. Meanwhile, in the case of the ground (see the ground reaction curve G6) causing a larger ground pressure, there is no intersection point between the bolt characteristic diagram G11 and the ground reaction curve G6. This is because the rock bolt 201 cannot withstand the ground pressure so that the rock bolt 201 is broken. When the rock bolt 201 is broken, a support function disappears. Specifically, if a ground pressure more than expected is applied, there is a possibility that the slippage failure between the rock bolt 201 and the fixing material 104 or the breakage of the rock bolt 201 may occur.

[0046] FIG. 7 shows a rock bolt 301 according to a reference example. As shown in FIG. 7(a), the reference example relates to a so-called slide type rock bolt 301. The rock bolt 301 includes a cylinder casing 302, a

piston 303, and a rod body 304. The piston 303 is attached to one end of the rod body 304. The piston 303 is accommodated in the cylinder casing 302. The piston 303 is movable in the center axis line direction of the rod body 304 inside the cylinder casing 302. The other end of the rod body 304 protrudes from the hole 103. The washer 19 and the bolt 21 are attached to the other end of the rod body 304. The outer peripheral surface of the rod body 304 is not provided with the unevenness as in the rock bolt 201. That is, the rod body 304 can follow the deformation of the ground 101 when the friction with the fixing material 104 is reduced.

[0047] The bolt characteristic diagram G12 of FIG. 4 shows a relationship between the extension of the rock bolt 301 and the stress generated in the rock bolt 301. When the ground 101 extends, the rod body 304 of the slide type rock bolt 301 slides with respect to the fixing material 104 and the piston 303 moves inside the cylinder casing 302 (see the extension $\Delta S5$ in FIGS. 4 and 7(b)). The states of the extension and the stress at this time are shown from the point P11 to the point P12 in the bolt characteristic diagram G12. As shown from the point P11 to the point P12 in the bolt characteristic diagram G12, stress caused by the movement of the rod body 304 does not occur in the rock bolt 301. That is, stress is uniform and does not increase from the initial state (see FIG. 7 (a)) of the rock bolt 301 to the state (see FIG. 7(b)) until the piston 303 contacts the cylinder casing 302. Then, the ground 101 is further deformed after the piston 303 contacts the cylinder casing 302 (see FIG. 7(b)). At this time, the rod body 304 cannot move in response to the deformation of the ground 101. Thus,

the rod body 34 extends to cope with the deformation of the ground 101 (see the extension $\Delta S6$ in FIGS. 4 and 7(c)). By the extension, stress is generated in the rod body 304 of the rock bolt 301.

5 [0048] When the ground 101 is deformed, the rod body 304 of the rock bolt 301 moves in response to the deformation. Thus, the entire length of the rock bolt 301 extends (see the point P11 to the point P12). Since the rock bolt 301 allows the deformation of the ground 101, the ground pressure of the ground 101 decreases with an increase in displacement amount. Next, the rod body 304 extends in response to the
10 deformation of the ground 101 after the piston 303 contacts the cylinder casing 302. Then, as indicated by the intersection point P13 between the ground reaction curve G4 and the bolt characteristic diagram G12, the rock bolt 301 reaches a support state when the ground pressure of the ground 101 and the stress of the rod body 304 are balanced.

15 [0049] According to the rock bolt 301, the deformation of the ground 101 is allowed to a certain degree. Thus, it becomes a support state while the ground pressure of the ground 101 decreases. Specifically, in the case of the ground 101 having ground characteristics indicated by the ground reaction curve G4, the ground pressure in the support state
20 (see the intersection point P13) of the rock bolt 301 is lower than the ground pressure in the support state (see the intersection point P7) of the rock bolt 201. In this way, the slide type rock bolt 301 can decrease the stress in the support state by allowing the deformation of the ground 101.

25 [0050] Meanwhile, the rock bolt 301 does not cause any force of supporting the ground 101 while the piston 303 moves inside the

cylinder casing 302 (from the point P11 to the point P12). Thus, there is concern that the rock bolt 301 may cause excessive looseness of the ground 101. This excessive looseness may cause the ground to collapse. When the ground has ground characteristics indicated by the ground reaction curves G1, G2, G3, and G4, the intersection points between the ground reaction curves G1, G2, G3, and G4 and the bolt characteristic diagram G12 indicating the support state all exist in a region exceeding an elastic limit. In other words, there is a possibility that the movement of the rod body 304 of the rock bolt 301 may include an unnecessary movement with respect to the ground having ground characteristics indicated by the ground reaction curves G1, G2, G3, and G4. Due to this unnecessary movement, the ground 101 is plastically deformed in the support state.

[0051] Next, a relationship between the displacement and the stress of the rock bolt 1 according to this embodiment will be described. Further, a relationship of the ground pressure with respect to the state of the displacement and the stress of the rock bolt 1 will be described. The bolt characteristic diagram G13 shown in FIG. 4 indicates a relationship between the displacement and the stress of the rock bolt 1.

[0052] The point P14 indicates a relationship between displacement and a force when the rock bolt 1 is in the initial state (see FIG. 3(a)). In the initial state, no stress is generated in the rock bolt 1. Next, a range from the point P14 to the point P15 indicates a relationship between the displacement and the stress when the rock bolt 1 is in the first state (a transition state from FIGS. 3(a) to 3(b)). In this range, a force corresponding to the stiffness of the compression spring 24 and the

contraction length of the compression spring 24 is generated. In addition, the displacement $\Delta S1$ from the point P14 to the point P15 corresponds to the movable length of the piston 15. Then, a range from the point P15 to the point P16 indicates a relationship between the displacement and the stress when the rock bolt 1 is in the second state (a transition state from FIGS. 4(b) to 4(c)). In this range, a force corresponding to the extension length and the stiffness in the fixed side extension portion 11 and the movable side extension portions 16, 17, and 18 having the extension $\Delta S2$ is generated. Additionally, the inclination of the bolt characteristic diagram G13 from the point P15 to the point P16 corresponds to the stiffness in the fixed side extension portion 11 and the movable side extension portions 16, 17, and 18. As indicated by the bolt characteristic diagram G13, the rock bolt 1 has two different displacement-stress relationship ranges.

[0053] When the ground 101 is deformed, the length L1 of the rock bolt 1 increases since the movable side rod body 3 moves in response to the deformation (see from the point P14 to the point P15). The rock bolt 1 allows the deformation of the ground 101. Thus, the ground pressure of the ground 101 decreases with an increase in displacement amount. Meanwhile, the rock bolt 1 generates stress in a direction A2 opposite to the movement direction A1 by the compression spring 24 with the movement of the movable side rod body 3. As indicated by the intersection point P17 between the ground reaction curve G4 and the bolt characteristic diagram G13, the rock bolt 1 reaches a support completion when the ground pressure of the ground 101 and the stress of the compression spring 24 are balanced.

[0054] Here, referring to the bolt characteristic diagram G13 and the ground reaction curves G1, G2, G3, G5, and G6 other than the ground reaction curve G4, it is understood that the bolt characteristic diagram G13 has intersection points P18 to P22 with any of the ground reaction curves G1, G2, G3, G5, and G6. That is, the rock bolt 1 can reach a support state in any ground having the ground characteristics indicated by the ground reaction curves G1 to G6. Thus, the rock bolt 1 can cope with a wide range of ground characteristics.

[0055] Further, the intersection points P17 to P22 indicating the support completion are all included in a range in which the deformation amount is smaller than those of the points P1 to P6 indicating the elastic deformation limit value. Thus, the rock bolt 1 can reach the support completion within the elastic deformation region. Generally, when the ground 101 is plasticized, the possibility of the strength being deteriorated with the lapse of time increases. Accordingly, it is desirable to support the ground in the elastic deformation region. Thus, the rock bolt 1 can support the ground 101 in an appropriate condition. Additionally, the ground 101 may reach the support state in the plastic deformation region.

[0056] Briefly, the movable side rod body 3 is moved along with the deformation of the ground 101 in the rock bolt 1. The deformation of the ground 101 is allowed by the movement of the movable side rod body 3 so that the ground pressure decreases. The movement of the movable side rod body 3 also generates stress due to the compression spring 24. Then, the fixed side extension portion 11 and the movable side extension portions 16, 17, and 18 are deformed after the movement

amount of the movable side rod body 3 becomes maximal. That is, the movable side rod body 3 and the fixed side rod body 2 are deformed after a change in ground pressure converges. This effect can be easily understood when compared with the effect of the rock bolt 301 of the reference example. That is, the rock bolt 301 of the reference example does not generate stress contributing to the support while the rod body 304 moves. Thus, there is concern that the rock bolt 301 of the reference example may allow excessive deformation of the ground 101. Meanwhile, the rock bolt 1 of this embodiment generates stress that contributes to the support caused by the compression spring 24 while the movable side rod body 3 moves. According to this the stress, even when the rod body 304 and the movable side rod body 3 have the same movement amount, the ground having the ground reaction curves G1 to G6 can be supported within the elastic deformation region. Thus, the rock bolt 1 can prevent excessive stress from being generated in the movable side rod body 3 and the fixed side rod body 2 while suppressing an excessive deformation of the ground 101.

[0057] In other words, in the rock bolt 1 according to this embodiment, the movable side rod body 3 moves and the fixed side extension portion 11 and the movable side extension portions 16, 17, and 18 slightly move due to the deformation of the ground 101 having a relatively large ground pressure. Uniform tension stress is generated in the fixed side extension portion 11 and the movable side extension portions 16, 17, and 18 so that the stress resists the ground pressure. When the displacement caused by the connection mechanism 6 reaches a slide length, the movement of the movable side rod body 3 is regulated.

Thus, the movable side rod body 3 cannot move by the slide length or more. The slide length is set as the movable range of the piston 15 inside the cylinder casing 22.

5 [0058] Although the slide length may be appropriately set to conform to the ground characteristic, there is a case in which the overburden height or the rock mass classification of the ground 101 cannot be accurately recognized in advance. Thus, a rock bolt that can widely follow the deformation of the ground having general ground reaction curves indicated by G1 to G6 in FIG. 4 is required.

10 [0059] In general, a steel material is used in the rock bolt. Examples of this steel material include STD510 (JIS M 2506-1992), SD345 (JIS M 2506-1992), SD295 (JIS M 2506-1992), and SS1232 (Swedish Industry Standard). Although these materials reach a yield point by the extension (strain) of about 0.2%, they subsequently undergo plastic deformation and extension from 15% to 20% to be broken. However, 15 the movable side rod body 3 and the fixed side rod body 2 of the rock bolt 1 except for the slide portion of the rock bolt 1 are fixed to the ground 101 through the fixing material 104 such as mortar. When the local deformation of the ground is taken into consideration, such extension just contributes to 50% or less of the deformation amount of 20 the rock bolt with respect to the deformation (the displacement) of the ground. It is desirable that the slide length of the rock bolt 1 is substantially the same as the plastic deformation amount for the entire length of the rock bolt except for the slide length of the slide portion. Specifically, the lower limit of the entire length of the rock bolt except 25 for the slide length of the slide portion may be 10% or more and

desirably 5% or more. The upper limit of the slide length may be 15% or less and desirably 20% or less. According to such a range, it is possible to widely follow the deformation of the general ground. Additionally, the "entire length of the rock bolt except for the slice length of the slide portion" mentioned herein indicates, for example, a length L1 from the other end of the fixed side rod body 2 to the other end of the movable side rod body 3 in the state in which the piston 15 is in contact with one end wall 22a as shown in FIG. 3(a). That is, it can be said that the rock bolt 1 is in the initial state and the rock bolt 1 is the shortest.

[0060] Further, it is desirable to set the bolt characteristic shown in the graph G13 of FIG. 4 to a desired characteristic in order to widely follow the deformation under various ground conditions. As shown in FIG. 4, the bolt characteristic is expressed by the relationship between the displacement and the stress (the ground pressure). The bolt characteristic can be controlled by the extension of the connection mechanism 6 of the rock bolt 1, the extension of the fixed side rod body 2 and the movable side rod body 3, or the arrangement of the fixed side anchors 7 and 8 of the fixed side rod body 2 and the movable side rod body 3. For example, the fixed side anchors 7 and 8 serving as knots generate a friction force and a resistance force with respect to the mortar as the fixing material. The friction force and the resistance force can be controlled by the arrangement interval or the dimensions (for example, the heights) of the fixed side anchors 7 and 8. According to the fixed side anchors 7 and 8, since a relatively large friction force and a relatively large resistance force can be generated, these forces are

effective to control the bolt characteristic.

[0061] Additionally, the above-described embodiment shows an example of the rock bolt according to the invention. The rock bolt according to the invention is not limited to the rock bolt according to the embodiment. For example, the rock bolt may be modified or applied to other purposes in the range not changing the gist described in each claim.

[0062] As shown in FIGS. 5(a) and 5(b), the anchor portion is not limited to the shapes of the movable side anchors 13 and 14 and the fixed side anchors 7 and 8 of the above-described embodiment as long as the relative position with respect to the ground 101 can be maintained and various shapes can be employed. An anchor portion 8C shown in FIG. 5(a) has a hump shape. Further, an anchor portion 8D shown in FIG. 5(b) has a shape in which a part of the rod body is bent in an S-shape.

[0063] As shown in FIGS. 5(c), 5(d), and 5(e), the slide control mechanism is not limited to the compression spring 24 as in the above-described embodiment as long as a resistance force can be generated at the time of moving the movable side rod body 3 and various configurations can be employed. A slide control mechanism 26 shown in FIG. 5(c) includes a compressible fluid 26b filled in a piston casing 26a. When the movable side rod body 3 moves, the compressible fluid 26b is compressed by the piston 26c. The slide control mechanism 27 shown in FIG. 5(d) includes a conical portion 27a provided in the movable side rod body 3. When the movable side rod body 3 moves, the conical portion 27a moves while entering resin 27c

filled in a piston casing 27b. According to this configuration, the apparent stiffness increases as the conical portion 27a enters the resin 27c. A slide control mechanism 28 shown in FIG. 5(e) includes a conical portion 28a provided in the movable side rod body 3. The ring 28b is disposed at a position separated from the conical portion 28a toward the opening by a predetermined distance. According to this configuration, since the shear failure of the fixing material 104 which is mortar is less likely to occur as the conical portion 28a approaches the ring 28b, the nominal stiffness increases.

[0064] Next, a rock bolt according to another embodiment of the invention will be described. As shown in FIG. 8, a rock bolt 1A according to another embodiment of the invention includes a main shaft 51, a ring 52, and a wire 53 (a position regulation portion, a flexible member). The ring 52 is a component different from the main shaft 51. Thus, the position of the main shaft 51 can change with respect to the ring 52.

[0065] The main shaft 51 includes a rod body 54 (a first member) and a sleeve 56. For example, the main shaft 51 may have a structure in which external threads provided on a first rod body portion 57 and a second rod body portion 58 are screwed into female threads provided in the sleeve 56 to be integrated.

[0066] The rod body 54 is a columnar rod body. The rod body 54 includes a first rod body portion 57 and a second rod body portion 58. The center axis line of the first rod body portion 57 and the center axis line of the second rod body portion 58 are disposed on the same virtual line. The first rod body portion 57 extends from one end 56a of the

sleeve 56 toward the opening 103a of the hole 103. The end portion of the first rod body portion 57 protrudes from the opening 103a. The fixing mechanism 4 is attached to a protruding end portion of the first rod body portion 57. Further, the second rod body portion 58 extends
5 from the other end 56b of the sleeve 56 toward the bottom 103b of the hole 103. The outer diameters of the first rod body portion 57 and the second rod body portion 58 may be substantially the same or different from each other. In this embodiment, it will be described that the first rod body portion 57 and the second rod body portion 58 have the same
10 outer diameter. For example, the outer diameters of the first rod body portion 57 and the second rod body portion 58 are equal to or larger than 20 mm and equal to or smaller than 30 mm.

[0067] The sleeve 56 is provided between the first rod body portion 57 and the second rod body portion 58. The sleeve 56 has a substantially
15 columnar shape and includes a base portion 59, a first taper portion 61, and a second taper portion 62. The base portion 59 has a uniform outer diameter D1 in the axial direction. The base portion 59 has a columnar shape and includes an outer peripheral surface 59a (an attachment surface) extending in the axial direction. The outer
20 peripheral surface 59a is provided with a plurality of ridges 59b (ridge portions) and the fixing material 104 is attached thereto in the initial state. Thus, the movement of the base portion 59 matches the movement of the fixing material 104 in the initial state. Meanwhile, when the deformation of the ground progresses, the attachment between
25 the base portion 59 and the fixing material 104 is broken. Thus, in this state, the movement of the base portion 59 does not match the

movement of the fixing material 104 and a slip occurs between the base portion 59 and the fixing material 104.

[0068] The outer diameters of the first taper portion 61 and the second taper portion 62 change in the axial direction. The first taper portion 61 is provided on the side of the opening 103a and includes one end 56a of the sleeve 56. Thus, the first taper portion 61 is connected to the first rod body portion 57. The second taper portion 62 is provided on the side of the bottom 103b and includes the other end 56b of the sleeve 56. Thus, the second taper portion 62 is connected to the second rod body portion 58. The outer diameter D1 of the base portion 59 is larger than the outer diameters D2 of the first rod body portion 57 and the second rod body portion 58. The maximum outer diameter of each of the first taper portion 61 and the second taper portion 62 matches the outer diameter D1 of the base portion 59.

[0069] The length L51 of the base portion 59 in the axial direction may be, for example, equal to or longer than 0.01 and equal to or shorter than 0.25 with respect to the length L52 of the main shaft 51 ($0.01 \leq (L51/L52) \leq 0.25$). Desirably, the length L51 may be equal to or longer than 0.025 and equal to or shorter than 0.1 with respect to the length L52 ($0.025 \leq (L51/L52) \leq 0.1$). Further, the length L51 of the base portion 59 in the axial direction may be, for example, longer than the length L53 of the first taper portion 61 in the axial direction. For example, the length L51 of the base portion 59 may be equal to or longer than 0.01 and equal to or shorter than 2 with respect to the length L53 of the first taper portion 61 ($0.01 \leq (L53/L51) \leq 2$). Desirably, the length L51 may be equal to or longer than 0.05 and equal to or shorter

than 1 with respect to the length L53 ($0.05 \leq (L53/L51) \leq 1$). More desirably, the length L51 may be equal to or longer than 0.125 and equal to or shorter than 0.75 with respect to the length L53 ($0.125 \leq (L53/L51) \leq 0.75$).

5 [0070] The ring 52 has a cylindrical shape and includes a front end surface 52a, a rear end surface 52b (a second contact portion), and a through-hole 52c (an insertion portion). The first rod body portion 57 is inserted through the through-hole 52c formed by perforating from the front end surface 52a to the rear end surface 52b. The outer diameter
10 D3 of the ring 52 is uniform in the axial direction. The outer diameter D3 of the ring 52 is larger than the outer diameter D1 of the base portion 59 of the sleeve 56. The inner diameter D4 of the through-hole 52c of the ring 52 is larger than the outer diameter D2 of the first rod body portion 57. Desirably, the inner diameter D4 is slightly larger than the
15 outer diameter D2 of the first rod body portion 57. Further, the inner diameter D4 of the through-hole 52c is desirably smaller than the outer diameter D1 of the sleeve 56. According to such a ring 52, the first taper portion 61 (the first contact portion) of the sleeve 56 (the first regulation portion) contacts the rear end surface 52b (the second contact portion) of the ring 52 (the second regulation portion). Thus, the ring
20 52 (the second regulation portion) and the sleeve 56 (the first regulation portion) constitute a slide regulation mechanism 23A.

[0071] Next, the operational effect of the rock bolt 1A will be described while comparing with the operational effect of a rock bolt according to a comparative example. As shown in FIG. 9, a rock bolt 200 according
25 to a comparative example is different from the rock bolt 1A of this

embodiment in that the ring 52 is not provided. Thus, the main shaft 51 of the rock bolt 1A according to the comparative example has the same configuration as the main shaft 51 of the rock bolt 1A according to this embodiment.

- 5 [0072] Mortar was filled as a fixing material in a pipe simulating a hole provided in the ground. Next, the rock bolts 1A and 200 were embedded in this mortar. At this time, a front end of the first rod body portion 57 was exposed from an opening of the pipe. Then, a front end of the first rod body portion 57 exposed from the mortar was gripped and a tensile load was applied in the axial direction of the rock bolt. The movement amount of a reference point provided on the first rod body portion 57 exposed from the mortar with respect to this tensile load was confirmed. This movement amount is caused by at least one of the extension of the rock bolt and the movement of the rock bolt.
- 10 [0073] FIG. 10 is a graph obtained by confirming the characteristic experiment of the rock bolt 1A according to the embodiment and the rock bolt 200 according the comparative example. A vertical axis of the graph indicates a load applied to the rock bolt. Further, a horizontal axis of the graph indicates the movement amount (the displacement) of the reference point provided on the rock bolt. That is, FIG. 10 shows a resistance force (a load) which is generated by the rock bolt with respect to the displacement of the ground. The bolt characteristic diagram G51 shows the result of the rock bolt 200 according to the comparative example. The bolt characteristic diagram G52 shows the result of the rock bolt 1A according to the embodiment.
- 20 [0074] First, the result (the bolt characteristic diagram G51) of the rock
- 25

bolt 200 according to the comparative example was confirmed. The bolt characteristic diagram G51 could be divided into two regions on the basis of the displacement (the horizontal axis). That is, a region F1 in which a load largely increases with respect to the displacement and a region F2 in which a load gently increases with respect to the displacement are provided. In the region F1, the attachment state between the rock bolt 200 and the fixing material 104 (mortar) is maintained and an extension corresponding to the stiffness of the rock bolt 200 with respect to the load is expected. Meanwhile, in the region F2, the attachment state between the rock bolt 200 and the fixing material 104 is not maintained and a slip of the rock bolt with respect to the fixing material 104 is expected. According to the bolt characteristic diagram G51, in the rock bolt 200 according to the comparative example, it is found that the region F2 in which a load gradually increases with respect to the displacement is dominant and only one load characteristic shown in the region F2 is obtained. That is, since the displacement of the rock bolt 200 is large when a large load is applied, it is found that there is a possibility that stress against the ground pressure of the ground cannot be obtained when the rock bolt is installed in the ground.

[0075] Next, the result of the rock bolt 1A according to the embodiment was confirmed. The bolt characteristic diagram G52 could be divided into three regions on the basis of the displacement (the horizontal axis). That is, a region F3 in which a load largely increases with respect to the displacement, a region F4 in which a load gently increases with respect to the displacement, and a region F5 in which a load largely increases

again with respect to the displacement are provided. That is, the rock bolt 1A according to the embodiment is different from the rock bolt 200 according to the comparative example in that the region F5 in which a load largely increases with respect to the displacement is generated after the region F4 in which a load gently increases with respect to the displacement. That is, since it is possible to decrease the displacement of the rock bolt 200 even when a large load is applied, it is found that stress against the ground pressure of the ground can be obtained when the rock bolt is installed in the ground.

[0076] First, in the region F3, an extension corresponding to the stiffness of the rock bolt 1A with respect to the load is expected similarly to the rock bolt 200 according to the comparative example. Next, also in the region F4, the attachment state between the rock bolt 1A and the fixing material 104 is not maintained and a slip of the rock bolt 1A with respect to the fixing material 104 is expected similarly to the rock bolt 200 according to the comparative example (see FIGS. 11(a) and 11(b)). The region F3 and the region F4 are different from each other in the attachment state between the rock bolt 1A and the fixing material 104. The attachment state is influenced by the ridge 59b provided in the outer peripheral surface 59a of the sleeve 56. Thus, when the surface shape of the outer peripheral surface 59a of the sleeve 56 is appropriately set, the extension from the region F3 to the region F4 can be set to a desired value. Further, it is considered that the resistance force of the region F4 is caused by the difference (corresponding to the projection area of the first taper portion 61 in a plane W orthogonal to the axial direction) between the outer diameter

D1 of the sleeve 56 and the outer diameter D2 of the first rod body portion 57 and the inclination of the first taper portion 61 with respect to the axis. Thus, it is found that the region F4 in the bolt characteristic diagram G52 can be controlled according to a desired characteristic on the basis of the shape of the sleeve 56.

[0077] Meanwhile, in the region F5 of the bolt characteristic diagram G52, the sleeve 56 contacts the ring 52 so that the movement of the main shaft 51 is disturbed (see FIG. 11(c)). This is because the resistance force increases when an area in which the ring 52 faces the fixing material 104 is larger than an area in which the sleeve 56 faces the fixing material 104 in a plane orthogonal to the movement direction of the main shaft 51. Thus, two load characteristics (the regions F4 and F5) can be realized by disposing the ring 52.

[0078] Further, it is found that the switching timing from the state of the region F4 to the state of the region F5 can be controlled when a distance L54 (see FIG. 8) between the sleeve 56 and the ring 52 is controlled. For example, when the distance L54 is set to be short, the switching from the state of the region F4 to the state of the region F5 can be performed with a relatively small displacement. Meanwhile, when the distance L54 is set to be long, the switching from the state of the region F4 to the state of the region F5 can be performed with a relatively large displacement. Thus, it is understood that the region F5 can be controlled according to a desired characteristic on the basis of the shape (particularly, the cross-sectional area) of the ring 52 and the distance L54.

[0079] Shortly, when the ground having the rock bolt 1A embedded

therein is deformed, the first rod body portion 57 has modes of moving with the deformation of the ground and being disturbed in the movement by the slide regulation mechanism 23A. According to these modes, the rock bolt 1A can provide different resistance forces corresponding to the respective modes to the ground. Thus, it is possible to cope with a wide range of ground characteristics.

[0080] Specifically, the rock bolt 1A can provide a first resistance force which is generated in a mode until the first taper portion 61 contacts the rear end surface 52b to the ground. Further, the rock bolt 1A can provide a second resistance force which is generated in a mode after the first taper portion 61 contacts the rear end surface 52b to the ground. Since the slide regulation mechanism 23A disturbs the movement of the first rod body portion 57 after the first taper portion 61 contacts the rear end surface 52b, the second resistance force is larger than the first resistance force. Thus, the rock bolt 1A can support the ground generating a relatively small ground pressure by the first resistance force. Further, the rock bolt 1A can support the ground generating a relatively large ground pressure by the second resistance force. Thus, the rock bolt 1A can cope with a wide range of ground characteristics.

[0081] As described above, the distance L54 between the sleeve 56 and the ring 52 is a factor for obtaining a desired characteristic. The distance L54 can be set to, for example, 30 mm or 40 mm. Thus, it is desirable to manage the distance L54 between the sleeve 56 and the ring 52. Here, the rock bolt 1A of this embodiment includes a wire 53 which manages the distance L54 between the sleeve 56 and the ring 52. One end of the wire 53 is fixed to a predetermined position (for

example, the base portion 59) of the sleeve 56. Further, the other end of the wire 53 is fixed to the ring 52. When the fixing mechanism 4 is attached to the rock bolt 1A and the rock bolt 1A is inserted into the uncured fixing material 104, the ring 52 connected to the sleeve 56 by a wire (a flexible member) is moved toward the opening 103a of the hole 103 during the insertion. At that time, since the ring 52 is connected to the sleeve 56 by the wire (the flexible member), the ring 52 can be disposed at a position separated from the sleeve 56 by a desired distance using the wire 53. Additionally, a wire different from the wire 53 is attached to the ring 52 and one end of the wire protrudes from the opening 103a. Then, the wire may be drawn after the rock bolt 1A has been inserted into the uncured fixing material 104. According to this configuration, the ring 52 can be reliably disposed at a position separated by a desired distance.

[0082] Briefly, the switching timing from the first resistance force to the second resistance force can be controlled by the distance L54 between the first taper portion 61 and the rear end surface 52b. Thus, since the wire 53 is provided, the slide regulation mechanism 23A can control the switching timing from the first resistance force to the second resistance force. Thus, the rock bolt 1A can generate a resistance force suitable for supporting the ground.

[0083] Specifically, according to a distance regulation portion which is the wire 53, the rear end surface 52b is not separated from the first taper portion 61 by the length or more of the wire 53. Thus, it is possible to suppress a distance from the first taper portion 61 to the rear end surface 52b from becoming a maximum distance or more.

[0084] Additionally, a configuration of managing the distance L54 between the sleeve 56 and the ring 52 is not limited to the wire 53. For example, as shown in FIG. 12, a protrusion portion 64 may be provided at a predetermined position of the first rod body portion 57. The protruding length of the protrusion portion 64 is larger than a gap between the outer peripheral surface of the first rod body portion 57 and the inner peripheral surface of the ring 52. Thus, the ring 52 does not move toward the front end of the first rod body portion 57 from a position in which the front end surface 52a of the ring 52 contacts the protrusion portion 64. Thus, it is possible to manage the distance L54 between the sleeve 56 and the ring 52.

[0085] Further, in this embodiment, the ring 52 has a cylindrical shape. The shape of the ring 52 is not limited to the cylindrical shape. As shown in FIG. 13(a), a ring 52A may include a through-hole 52c through which the first rod body portion 57 is inserted and a through-hole 52d which is different from the through-hole 52c. Further, as shown in FIG. 13(b), the ring may include the through-holes 52c and 52d and a notch portion 52e provided in an outer peripheral portion of a ring 52B. Furthermore, the ring may include the through-hole 52c and the notch portion 52e provided in the ring 52B (not shown). According to the through-hole 52d or the notch portion 52e, it is possible to control an area facing the fixing material 104. For example, when an area facing the fixing material 104 is set to be small, it is possible to suppress a resistance at the time of the insertion into the uncured fixing material 104. Further, an area in which the front end surface 52a of the ring 52 faces the fixing material 104 also influences the load (the resistance

force) with respect to the displacement. Thus, it is possible to control a relationship between the displacement and the load in the state after the sleeve 56 contacts the ring 52.

[0086] Further, the rock bolt 1A includes one set of the ring 52 and the sleeve 56, but the invention is not limited thereto. For example, as shown in FIG. 14, the rock bolt 1B may include two or more sets of the ring 52 and the sleeve 56. According to this configuration, it is possible to reliably obtain the load-displacement characteristic using the slide regulation mechanism 23A.

Reference Signs List

[0087] 1, 1A: rock bolt, 2: fixed side rod body (second member), 3: movable side rod body (first member), 4: fixing mechanism, 6: connection mechanism (slide connection mechanism), 7, 8: fixed side anchor, 9: fixed side shaft portion, 11: fixed side extension portion, 12: movable side shaft portion, 13: movable side anchor (first anchor portion), 14: movable side anchor, 15: piston (first regulation portion), 16: movable side extension portion (first extension portion), 17: movable side extension portion (second extension portion), 18: movable side extension portion, 22: cylinder casing, 22a: one end wall, 22b: other end wall (second regulation portion), 23, 23A: slide regulation mechanism, 24: compression spring (slide control mechanism), 51: main shaft, 52: ring (second regulation portion), 53: wire (distance regulation portion), 54: rod body, 56: sleeve (first regulation portion), 57: first rod body portion (first member), 58: second rod body portion, 59: base portion, 61: first taper portion (first contact portion), 62: second taper portion, 52a: front end surface, 52b: rear end surface (second

contact portion), 52c: through-hole (insertion portion), 101: ground, 103: hole, 104: fixing material, G1 to G6: ground reaction curve, G11, G12, G13, G51, G52: bolt characteristic diagram.

CLAIMS

1. A rock bolt which is embedded in a hole provided in ground, comprising:

a first member that is a rod body extending in a predetermined direction and is disposed inside the hole; and

a slide regulation mechanism which disturbs a movement of the first member in accordance with deformation of the ground,

wherein the slide regulation mechanism includes:

a first regulation portion which is fixed to the first member, and

a second regulation portion which is separated from the first member by a predetermined distance between the first regulation portion and an opening of the hole and contacts the first regulation portion when the first member moves in accordance with the deformation of the ground.

2. The rock bolt according to claim 1, further comprising:

a second member that is a rod body extending in the predetermined direction and is provided in parallel to the first member inside the hole;

a slide connection mechanism which connects one of the first member and the second member to the other thereof to be relatively movable; and

a slide control mechanism which generates a force in a direction opposite to a movement direction when one of the first member and the second member moves with respect to the other thereof,

wherein the first member includes a first extension portion

which is elastically deformable,

wherein the slide regulation mechanism regulates a range in which one of the first member and the second member is movable with respect to the other thereof, and

5 wherein the stiffness of the first extension portion is larger than the stiffness of the slide control mechanism.

3. The rock bolt according to claim 2,

wherein the slide connection mechanism connects one end of the first member and one end of the second member to each other,

10 wherein the slide regulation mechanism defines a maximum length from the other end of the first member to the other end of the second member, and

wherein the first member includes a first anchor portion which is provided at the other end side in relation to the first extension portion and maintains a relative position with respect to the ground.

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4. The rock bolt according to claim 3, further comprising:

a fixing mechanism which is attached to the other end side in relation to the first anchor portion and maintains a relative position with respect to the ground,

20 wherein the first member further includes a second extension portion which is provided between the other end and the first anchor portion.

5. The rock bolt according to claim 3 or 4,

wherein the slide control mechanism is a compression spring.

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6. The rock bolt according to any one of claims 3 to 5,

wherein a cross-sectional area of the first anchor portion is

larger than a cross-sectional area of the first extension portion.

7. The rock bolt according to claim 1,

wherein the first regulation portion includes a first contact portion which contacts the second regulation portion of the slide regulation mechanism, and

wherein the second regulation portion includes an insertion portion through which the first member is inserted and a second contact portion which is provided to surround the insertion portion and with which the first contact portion comes into press-contact.

8. The rock bolt according to claim 7,

wherein the slide regulation mechanism further includes a distance regulation portion which regulates a maximum distance between the first regulation portion and the second regulation portion.

9. The rock bolt according to claim 8,

wherein the distance regulation portion is a flexible member of which one end is fixed to the first regulation portion and the other end is fixed to the second regulation portion and which has a length corresponding to the maximum distance.

10. The rock bolt according to claim 8,

wherein the distance regulation portion is a protrusion portion which is provided at a position separated from the first regulation portion in the extension direction of the first member by a distance corresponding to the maximum distance.

11. The rock bolt according to any one of claims 7 to 10,

wherein the first regulation portion includes an attachment surface which extends in the predetermined direction and to which a

fixing material filled in the hole is attached, and

wherein the attachment surface is provided with a ridge portion protruding from the attachment surface.