United States Patent

Williams

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[45] **Oct. 3, 1972**

[54] **ROCK BOLTS**

[72] Inventor: **Chester I. Williams,** 347 Greenbriar, S.E., Grand Rapids, Mich. 49506

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[21] Appl. No.: **8,345**

[52] **U.S. Cl.**..........................**61/45 B,** 52/698, 85/75

[51] **Int. Cl.**..**E21d 20/02**

[58] **Field of Search**.........61/45 B; 52/704, 707, 698, 52/156, 166; 85/73, 75

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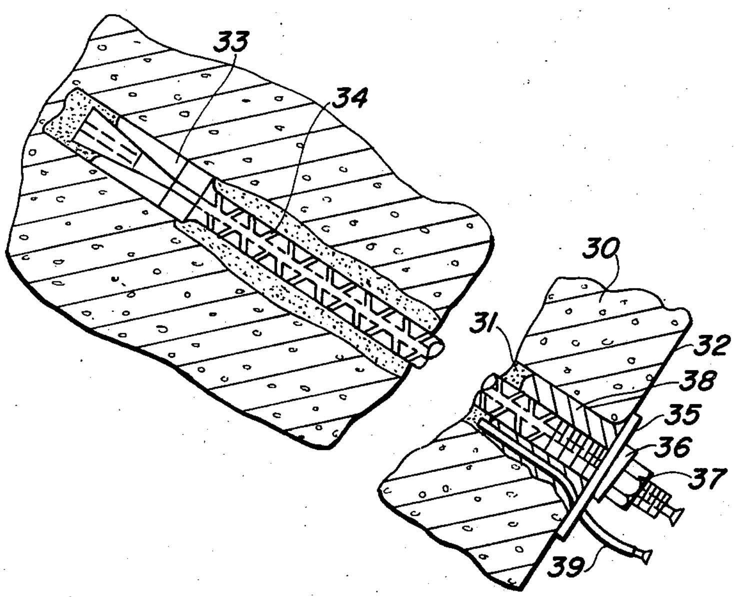
Primary Examiner—Dennis L. Taylor
Attorney—Glenn B. Morse

[57] **ABSTRACT**

A method of reinforcing a rock formation with rock bolts establishing a lock-in pre-stress condition inhibiting the initiation of movement of the formation, and structural features of a rock bolt assembly capable of use in the practice of the method.

4 Claims, 20 Drawing Figures



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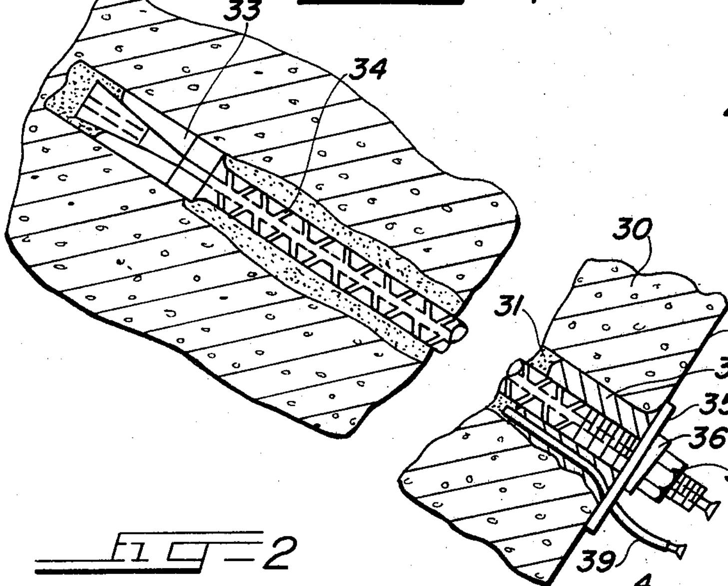
SHEET 1 OF 5

FIG-1



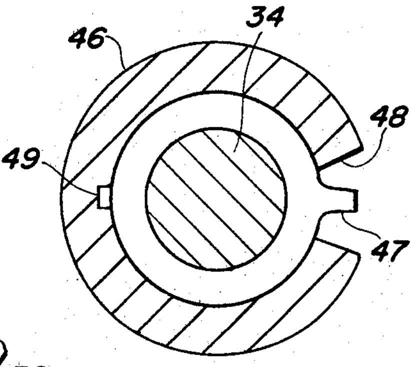


FIG-4

FIG-2

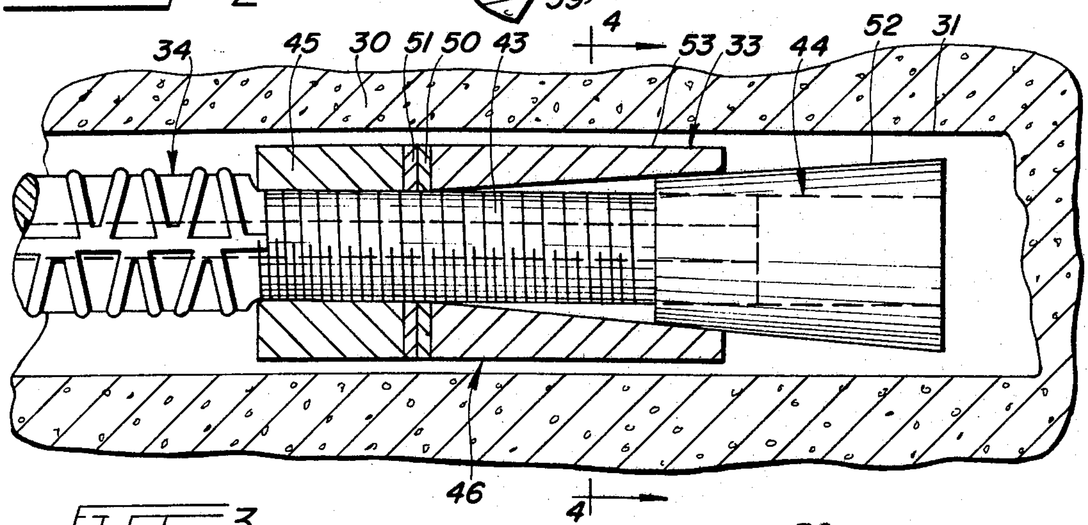


FIG-3

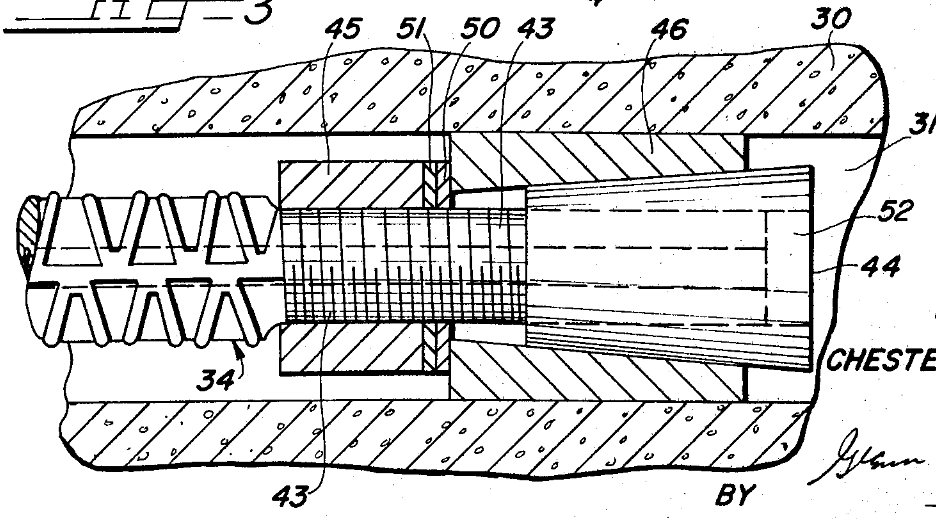


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FIG-5

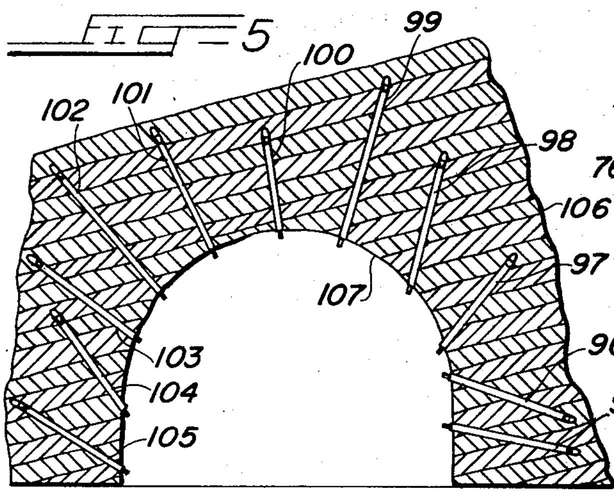


FIG-8

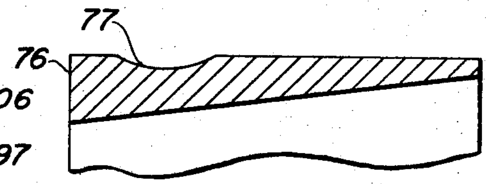
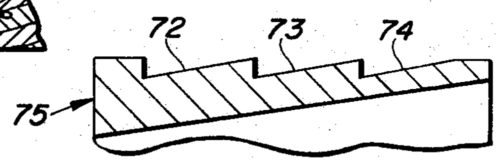


FIG-9



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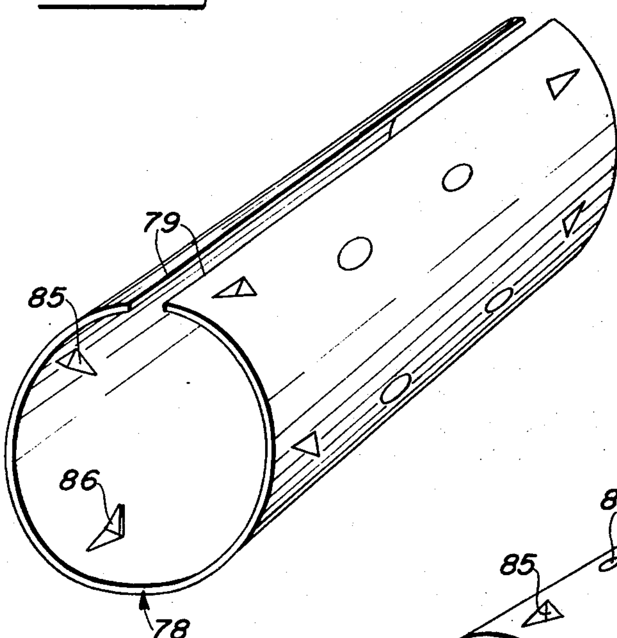

FIG-6

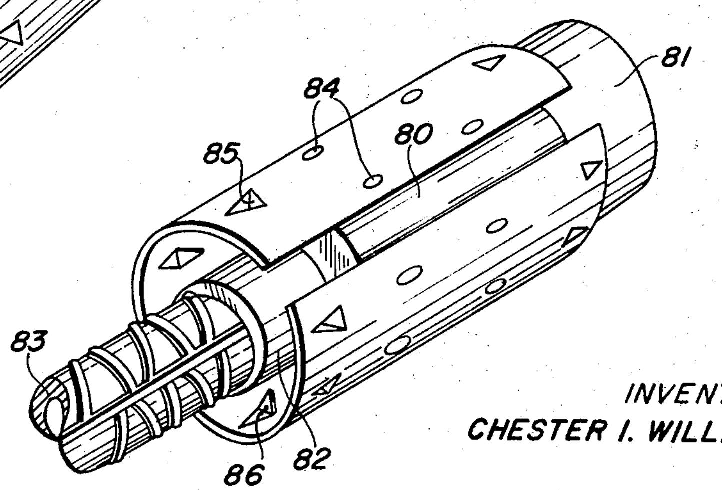

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FIG. 10

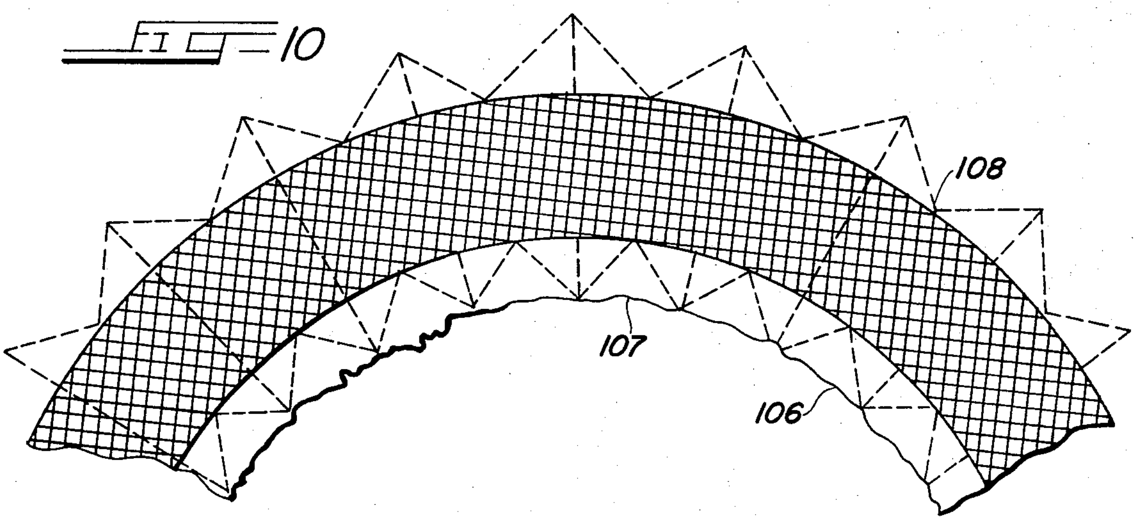

FIG. 11

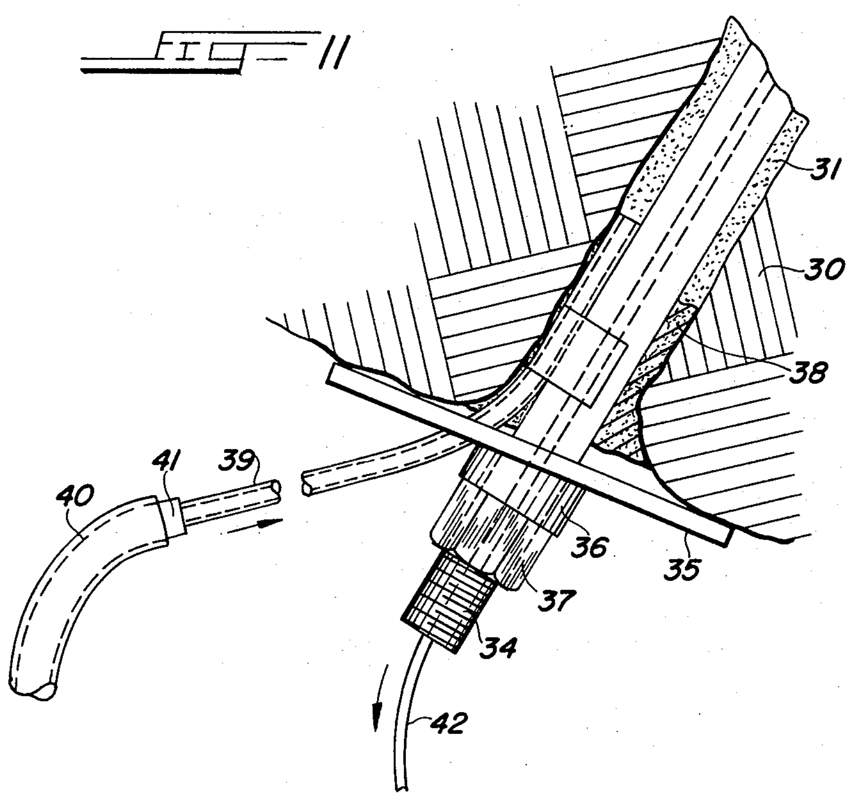

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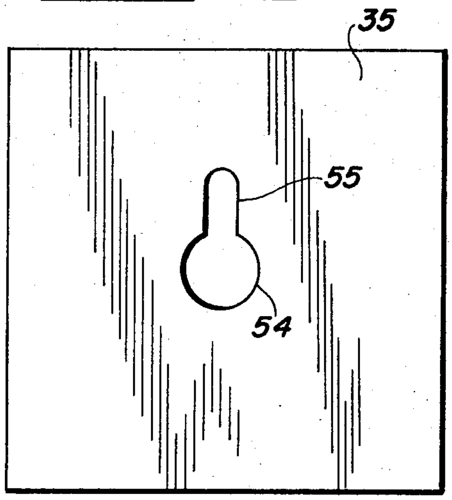
FIG-12



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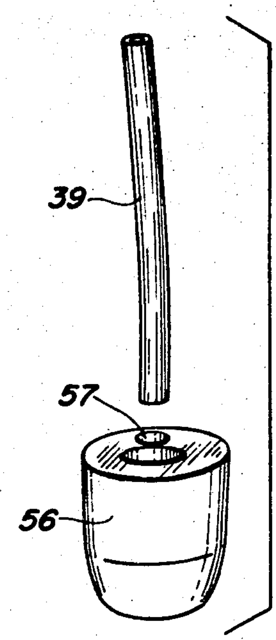

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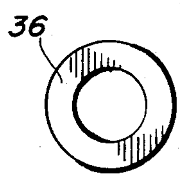

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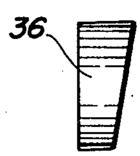

FIG-16

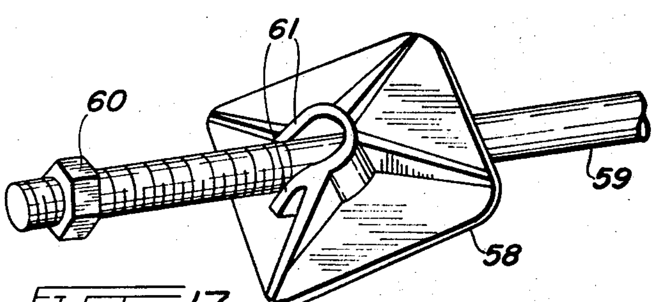

FIG-17

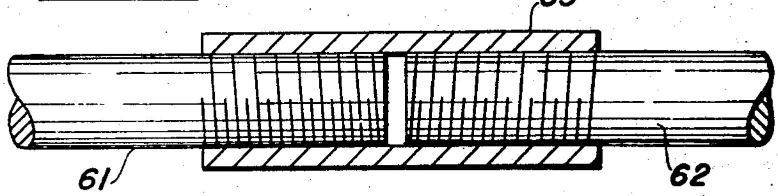

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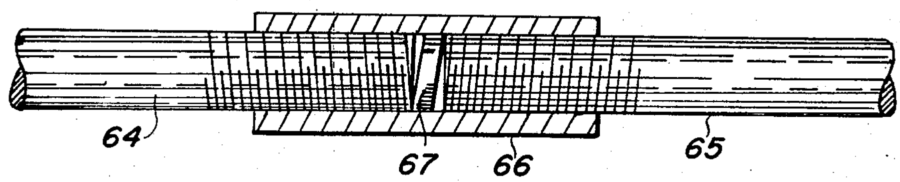
FIG-18



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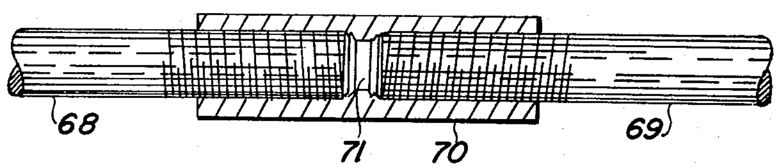

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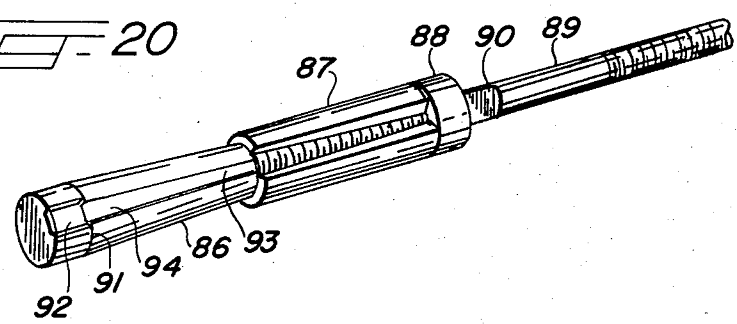

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ROCK BOLTS

BACKGROUND OF THE INVENTION

It is generally recognized that a stratified or fractured rock formation can be held in place by the use of bolts extending from the surface inward to a sufficient depth to suit the requirements of the particular conditions. Bolts of 40 feet in length are not uncommon. It has also been established that rock laminae can be locked together with bolts to function as a self-supporting beam to form the roof of tunnels or other excavations. It is common practice to provide anchor devices at the inner ends of the bolts so that some degree of tension can be developed between that point and a bearing plate placed over the surface opening of a hole in which the bolt is installed. These bolts are frequently given a protective covering and a bonding to the rock by injecting grout in the hole around the bolt rod.

A peculiarity of materials under stress has presented a problem in the design and installation of these rock bolts. It is fundamental that a bolt rod must be stretched in order to develop tension. It follows that a bolt installed without some degree of pre-stress will exhibit no restraining power on the rock formation until the formation actually begins to move. This is precisely the condition that the bolt is installed to prevent. It is not only desirable to preserve the solidity of the rock formation insofar as is possible, but it is also desirable to obtain the benefits of the well-known "stick-slip" friction characteristics which result in making it much easier to hold a movable object in place prior to actual commencement of movement than it is afterward.

Prior anchoring devices have generally proven inadequate to sustain the full load capability of the bolt rod, so that reliance had to be made on a bond between the bolt and the rock formation through the surrounding grout in order to develop the full load capability of any particular rock bolt installation. As long as reliance upon the grout was necessary, it is clearly out of the question to develop more than a relatively minor degree of pre-stress. Rock bolt installations were developed around these limitations. Once the grout had "set", further pre-stress could not be considered due to the fact that the bolt became locked to the rock formation along its full length. It was therefore incapable of any further stretching, which would be necessary for any increase in stress. A further problem associated with conventional anchor devices is the general impossibility of grouting the anchor along with the bolt rod. This is due to the fact that these devices did not adequately provide for flow of the grout along the full length of the bolt assembly, including the anchor, nor for a passage of the grout along beside the anchor. Either a hollow bolt rod or a separate conduit must be provided extending over the full length of the assembly, or it is obvious that the grout cannot be deposited beyond the end of the bolt assembly with any degree of certainty. It is also obvious that these conditions render adequate inspection of a completed bolt assembly, particularly with regard to the completion of the grouting, almost impossible. In summary, prior rock bolt assemblies have not been designed such that the adequacy of the installation is immediately evident to an inspector whose observations are necessarily confined to the surface area of the installation.

SUMMARY OF THE INVENTION

The present invention provides a method which can preserve the initial placement of a rock formation by applying pre-stress to an intensity corresponding to a working load of the rock bolt rod, which is related to the yield strength of the rod material, thus utilizing the primary strength characteristic of the bolt that would not involve displacement of the rock formation. The components of a rock bolt assembly are adapted to permit this degree of pre-stress, and also permit the injection of grout to the point of full recirculation within the bolt hole throughout the length of the bolt assembly, including the anchor device. The bolt is also adapted to be disengaged from the hole in the formation prior to grouting, if it is discovered during the setting of the anchor device that the rock formation is too soft or fractured to sustain the necessary intensity of set. This latter feature is obtained by utilizing a rotatively set anchor in combination with rod-section coupling having differential disengagement torque.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional elevation showing the installation of a rock bolt assembly in a hole in a rock formation inclined upwardly from the entrance.

FIG. 2 is a sectional elevation on an enlarged scale over that of FIG. 1, showing the un-expanded condition of an anchor device.

FIG. 3 is a view of the mechanism shown in FIG. 2, in the expanded condition.

FIG. 4 is a transverse section on the plane 4—4 of FIG. 2, on an enlarged scale.

FIG. 5 is a schematic illustration showing a typical installation of a pattern of rock bolts to secure a rock formation over a tunnel.

FIG. 6 is a perspective view of an anchor provided with a resilient shim sleeve.

FIG. 7 is a perspective view of the shim sleeve shown in FIG. 6, on an enlarged scale.

FIG. 8 is a fragmentary axial section through an expansible shell with one form of a peripheral concavity.

FIG. 9 is an axial section of an expansible shell with a modified form of peripheral concavity.

FIG. 10 is a diagram illustrating the stress condition in a rock formation resulting from the installation of a pattern of rock bolts.

FIG. 11 is a view of the surface components of a rock bolt installation, and illustrating the application of grout.

FIG. 12 is a plan view of a surface bearing plate.

FIG. 13 is an exploded view showing a stopper for insertion in the entrance of the bolt hole, in conjunction with a vent tube insertable in the side passage in the stopper.

FIG. 14 is a plan view of a bevel washer used with the surface components of the rock bolt assembly.

FIG. 15 is a side elevation of the washer shown in FIG. 14.

FIG. 16 is a perspective view of a form of bearing plate capable of accommodation to large angles of deviation from a perpendicular relationship between the plane of the surface of the rock formation and the axis of the bolt rod.

FIG. 17 is a sectional elevation of a from of coupling uniting sections of the bolt rod.

FIG. 18 is a sectional elevation showing a modified form of locking arrangement for controlling back rotation of a coupling connection uniting two rod sections.

FIG. 19 is a sectional elevation showing a further modification of coupling arrangement uniting adjacent rod sections.

FIG. 20 illustrates a modified form of anchor assembly providing a relatively greater shell area, and adapted to prevent pull-through of the cone member in soft rock conditions.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates a typical installation of a rock bolt assembly in a rock formation **30**, which has been prepared by drilling a hole **31** from the surface **32** to a sufficient depth to involve the desired amount of the rock formation in the securing effect of the rock bolt installation. The rock bolt assembly includes the anchor device **33**, a bolt rod **34** (which may be in one piece, or a series of axially interconnected sections), a surface plate **35**, a bevel washer **36**, and a standard nut **37**. FIG. 1 illustrates the condition of the installation immediately after "grouting", in which a charge of liquid cementitious material is injected into the hole **31** surrounding the bolt rod and the anchor device to provide a protective sheathe around these components, and to bond them to the rock formation throughout the length of the assembly. To facilitate the grouting operation, a sealant packing **38** is jammed into the entrance of the hole **31** around the bolt rod, and the bearing plate **35** is placed down over it. The flexible tube **39** traverses this packing, and becomes a means for carrying the grout into the hole.

Grout should always be injected at the low end of a hole, with provision being made for the exhaust of the entrapped air as the charge of grout advances. Since the hole is inclined upwardly from the entrance in the FIG. 1 installation, grout is injected through the tube **39**, which represents the low end of the hole in this form of installation. As the grout progressively fills the hole, air is withdrawn through the conduit formed by the hollow interior of the bolt rod **34**. The injection of the grout continues through the tube **39** until the hole is completely filled, which is indicated by movement of grout down through the bolt rod to the point where it emerges at the surface, in the manner illustrated in FIG. 11. The injection of the grout is accomplished by any conventional form of grout pump, which has a delivery tube **40** provided with a convenient adapter **41** for receiving the tube **39**. A pump of the type described in my U.S. Pat. No. 3,227,426 is recommended. The stream of grout **42** emerging from the end of the bolt rod **34** provides a positive indication that the hole **31** has been completely filled. After the grouting operation has been completed, the hole in the bolt rod **34** from which the grout is shown emerging in FIG. **11**, together with the tube **39**, are plugged as shown in FIG. 1 to sustain at least some degree of grout pressure within the hole **31** until a complete set has taken place. After this has occurred, the tube **39** has no further use. The diameters of the holes in the bolt rod **34** and in the tube **39** are of the order of a quarter of an inch, or larger (depending on rod diameter) and it has been found that plugs in the general shape of golf tees have been very effective and easy to handle in performing this sealing operation. These can be removed, if desired, after the grout has set. If the hole **31** were inclined downwardly from the entrance, the flow of grout would be reversed. It would be injected through the bolt rod, since that would form a conduit leading to the lower extremity of the hole in the rock formation. Emergence of the grout through the tube **39** would then give the indication of a completed grouting operation. In either case, it will be noted that this completion is assured by at least a momentary complete recirculation of grout within the hole **31** throughout the length of the rock bolt assembly. Some forms of rock bolt assemblies utilize a solid rod, rather than the hollow form illustrated in the drawings. When the solid rod is used, a side tube of the general nature of the tube **39** is lashed in some convenient form to the bolt rod, and preferably extends over the full length of the entire rock bolt assembly. One advantage to the use of the hollow bolt rod is the freedom of the assembly from displacement of the full-length tube which is likely to occur as the anchor device **31** is "set" by rotation of the rod from the surface.

The securing of the anchor device **33** is illustrated in FIGS. **2** and **3**. The components of the anchor device are shown installed on the threaded end **43** of the rod section **34**. A cone member **44** has a threaded central opening extending throughout its length, and is normally in threaded engagement with the rod section **43**. A thrust ring **45** is also in threaded engagement with the rod section **43**, and is disposed at the extremity of the threaded portion of this section. The expansible shell **46** surrounds the cone member **44**, and is axially interposed between the cone and the thrust ring **45**. Relative rotation between the rod section **34** and the cone **44** will result in movement of the cone **44** toward the axially-fixed thrust ring **45**, resulting in the expansion of the shell **46**. This shell is C-shaped in cross-section, as best shown in FIG. **4**. To assure that the shell does not rotate on the cone **44**, the cone is provided with a key ridge **47** located within the discontinuity **48** of the C-shaped cross-section of the shell **46**. This discontinuity is provided to facilitate the expansion of the shell, and works in conjunction with the point of weakness established by the axial groove **49** on the opposite side of the shell. This portion of the shell functions somewhat in the manner of a hinge as the cone **44** advances to the left, as shown in FIGS. **2** and **3**. Fracturing takes place initially in the shell adjacent the notched area **49**, as the cone proceeds from the FIG. **2** to the FIG. **3** position. The setting of the anchor must proceed to the point where the shell is jammed solidly against the wall of the hole **31** with a sufficient intensity of force to permit the anchor assembly to resist the full working load of the bolt rod **34**, which corresponds to the yield strength of a selected steel rod commonly anywhere from an inch to two inches or more in diameter.

While the initial setting operation is performed by rotation of the rod **34**, an examination of the configuration of the components of the anchor assembly shown in FIG. **2** will make it obvious that a subsequent movement to the rod to the left, once the shell **33** has been solidly placed against the rock formation, will result in further movement of the cone into the shell (accompanied by a movement of the thrust ring **44** away from the adjacent end of the shell as the axial rod movement takes place). It is nevertheless preferable that the initial set of the anchor assembly by rotation should be sufficient to resist all of the applied loading. This degree of anchor set will permit a much easier pre-stressing operation, which is accomplished by progressively tightening the nut **37** to a predetermined torque determined by the yield strength of the particular steel selected for the bolt rod **34**, and by the cross-sectional area of this rod. These torque requirements are sufficiently high to present a real problem in the axial securing of the thrust ring **45**. Because of the intensity of the forces involved, there is a strong tendency to frictionally induce continued rotation of the thrust ring with respect to the bolt rod during the setting operation, and to thus strip out the threaded engagement between the thrust ring **45** and the bolt rod. It is preferable to provide a shoulder against which the thrust ring can advance, and also provide a diameter-length relationship of the thrust ring such that the threaded length is approximately equal to the diameter. This relationship makes it possible to keep the diameter of the thrust ring sufficiently low to be less than the unexpanded diameter of the shell **46**, and thus facilitate the insertion of the anchor assembly into the hole **31**, and eliminate any substantial interference with the axial flow of grout to or from the end of the anchor through the unclosed C area of the shell and over the hardened slip washers and thrust rings. To further facilitate relative rotation between the thrust ring **45** and the shell **46**, it is preferable to incorporate a pair of hardened slip rings **50—51**, which may be coated with oil or grease to minimize the torque transfer between the shell and the thrust ring.

The proportions of the thrust ring specified above operate best in conjunction with a particular slope relationship on the periphery of the cone **44**. The elements of the cone **44** are disposed at an angle with respect to the axis of the rod **34** of less than fifteen degrees, with ten degrees giving the best performance. The conical periphery **52** engages a similarly shaped surface on the inside of the shell **46**, the walls of which are wedge-shaped in axial cross-section. The fracturing of the shell as the expansion proceeds therefore generates a group of wedges spaced around the periphery of the conical surface **44** as the anchor takes hold of the walls of the hole **31**. During the entire expansion of the anchor, these wedge sections move out in positions parallel to the original un-expanded condition, with at least the major portion of the periphery **53** of the shell remaining parallel to the axis of the bolt rod **34**.

The surface components of the bolt rod assembly are shown in FIGS. **12** to **15**. The surface plate **35** has a "-keyhole" shaped opening including the central portion **54** sized to receive the bolt rod **34**. The lateral extension **55** from the central portion **54** is too small to receive the bolt rod, and is provided for accommodating the flexible tube **39**. This arrangement prevents the rock bolt from migrating to a position in which the flexible tube **39** is pinched off. The lateral extent of the portion **55** of the opening is such that it reaches beyond the diameter of the bevel washer **36** shown in FIGS. **14** and **15**. The tube is thus permitted to emerge from the plate **35** at a position where it cannot be pinched off by the rod, the bevel washer, or by the nut **37**. This arrangement is shown and claimed in my U.S. Pat. No. 3,234,732. Using a single washer **36**, the alignment of the components to accommodate a particular angular relationship between the bolt axis and the surface of the rock formation can only be approximate. By the use of a pair of these washers, however, it becomes possible to adjust the assembly to an exact angular relationship so that the bearing forces are transmitted uniformly around the opening **54**, rather than exclusively at one point. The two washers constituting the pair can be rotatively adjusted with their beveled faces interengaged so that the slant between the two outer faces are then exactly in conformity with the alignment of the bolt axis and that of the plate pressed against the face of the rock formation. With the pair maintained in this relative angular position, they can then be rotated together to the correct position of the pair with respect to the plate. The arrangement of a pair of these washers for adjustment in this manner normally will require a slightly greater clearance between the diameter of the bolt rod and the inside diameter of the washers, as the washers assume a canted relationship on the rod.

The stopper **56** shown in FIG. **13** can be used in place of the mass of sealant packing **38** illustrated in FIG. **1**. The stopper **56** functions in the manner of a cork, and is provided with the small opening **57** extending axially within one side wall for receiving the tube **39**. The plug **56** is preferably of rubber or some material of similar characteristics. Another possible variant in surface assembly is illustrated in FIG. **16**, in which a bearing plate **58** is used in conjunction with a bolt rod **59**, where the angular relationship is greater than that which can readily be accommodated by the bevel washer shown in FIGS. **14** and **15**. The nut **60** (either directly, or through a suitable heavy washer) bears against the inclined arcuate flanges **61** for the transmission of bolt forces through the bearing plate **59** over to the rock formation. Bearing plates of this type are usually fabricated of relatively heavy malleable cast iron.

The inevitable variations in conditions in a rock formation which may be expected in the installation of large numbers of rock bolts are such that it frequently becomes necessary to disengage an anchor that has only been partially set. This situation occurs when the rock formation appears to be too soft to take the full intensity of set of the anchor, or the anchor appears to have been lodged in a fractured area that did not have sufficient density to accommodate the necessary pressures. In such cases, it is desirable to back-rotate the anchor assembly from the FIG. **3** to the FIG. **2** positions. Since it is common practice to make up the lengths of relatively long bolt rods in a number of sections interconnected by couplings, it is obvious that a problem arises the moment one attempts to back-rotate the anchor assembly. To assure that all of such back-rotation takes place at the anchor rather than at any one of the couplings, the arrangements shown in FIGS. **17**, **18**, and **19** can be used. In FIG. **17**, the threaded ends of the rod sections **61** and **62** terminate at such a point that these rod sections are threaded into the coupling **63** to the maximum extent prior to the interengagement of the ends of the rod sections **61** and **62**. The wedging action developed at the ends of the threaded portions of the rod sections produce a jamming action when the coupling is solidly tightened of a sufficient intensity to create a friction resistance to back-rotation which is in excess of the back-rotation torque required to un-set the anchor assembly. A similar effect is produced in quite a different way by the arrangement shown in FIG. **18**, in which the rod sections **64** and **65** are interconnected by the coupling **66**. No attempt has been made in this arrangement to control the length of threaded interengagement, but the lock washer **67** is interposed between the ends of the rod sections. As the coupling is tightened down in the illustrated position, the presence of the lock washer tends to inhibit back rotation such as would loosen the coupling. In FIG. **19**, an effect is produced which is quite similar in principle to that illustrated in FIG. **17**. In this case, however, the rod sections **68** and **69** are threaded to any convenient length in excess of half the length of the coupling **70**, and the coupling itself is provided with a discontinuous threading leaving the central portion **71** with incomplete threads. Each of the rod sections **68** and **69** is thus threaded in as far as it will go, and the coupling is then given a severe tightening torque, resulting in a binding action at the incomplete threads in the center portion of the coupling. The central hole at the rod ends should be bevelled (countersunk) to minimize flow resistance to grout in all cases.

FIGS. **8** and **9** illustrate modified forms of the anchor shell which facilitate the development of the frictional and pressure-centered retaining forces characteristic of the anchor assembly described in connection with FIGS. **2** and **3**. It is common practice in the design of anchors to utilize a saw-toothed exterior, with the generally radial faces arranged to confront the pull-out forces operating against the anchor. In other words, the anchor shell is expected to act something along the line of a broach or file. Applicant has discovered that this principle is less effective than the use of a completely opposite orientation of the peripheral irregularities. In other words, the pull-out strength of the anchor based only upon the shear strength of the immediately surrounding rock formation is likely to develop less retaining force than a high degree of pressure exerted normally against the sloped surfaces **72–74** of the shell **75** shown in FIG. **9**. In FIG. **8**, the shell **76** has an arcuate depression **77**. Preferably, both this depression and the notched-shaped irregularities **72–74** of FIG. **9** are annular. In the case of the sloped surfaces **72–74**, it is preferable that these be kept at around ten degrees with respect to the axis of the bolt rod. Correspondingly, tangents to the curved surface **77**, particularly at the inner (right-hand) extremity of the shell, should be at approximately ten degrees with respect to the axis of the bolt rod.

FIGS. **6** and **7** illustrate arrangements that may be used when it appears that a bolt hole has been drilled somewhat oversized with respect to the anchor unit to be installed. The C-shaped shim sleeve **78** has a discontinuity at **79** which permits circumferential expansion along with the expansible shell **80** around which the sleeve has been installed, as shown in FIG. **6**. The anchor assembly is the same as that illustrated in FIGS. **2** and **3**, and includes the cone **81** and the thrust ring **82** assembled to the bolt rod **83**. The shim sleeve may be provided with a random number of holes as shown at **84** to facilitate the gripping action against the rock formation, but this is entirely optional. Inwardly turned tabs as shown at **85** and **86** are provided at both ends for axial interengagement with the ends of the shell **80** to locate the shim sleeve with respect to the anchor assembly.

FIG. **20** illustrates a form of anchor assembly that can be used particularly well in relatively soft rock formations where a greater surface area on the shell is desirable. Comparison between FIG. **20** and FIG. **1** will bring out the relatively greater axial length of the shell in the FIG. **20** modification. The slope of the peripheral surface of the cone **86** is received within the similarly shaped interior surface of the shell **87**, which is restrained axially by the presence of the thrust ring **88**. FIG. **20** illustrates the use of a solid bolt rod **89**, in which the axial positioning of the thrust ring **88** is supplemented by the presence of the forged flat **90**. The cone **86** is provided with a shoulder **91** formed by a cylindrical enlargement of the diameter of the cone at that point, and this shoulder is discontinuous at the point **92**. The reason for this discontinuity is to allow for the flow of grout through an area which might otherwise be obstructed by the presence of the shoulder **91**. In order to assure the flow of grout completely around all surfaces of the cone which are exposed, it is preferable that the key ridge **93** be disposed opposite the discontinuity **92**, and that the discontinuity be somewhat wider than the key ridge at that point. To further facilitate the flow of grout, it is preferable to provide the inclined surface **94** to define the end of the key ridge **93**, rather than permitting this member to come to an abrupt shoulder at that point. The height of the key ridge **93** then may be considered to decrease to zero approaching the discontinuity **92**.

FIG. **5** illustrates a typical installation of a series of rock bolts to maintain the integrity of the rock formation over the upper portion of a tunnel. The bolts assemblies **95–105** are all installed in the rock formation in a manner similar to that shown in FIG. **1**, but in varying attitudes with respect to the horizontal. Grouting techniques will vary accordingly, as described previously. The prestressed installation of these bolts is capable of binding the laminae of the rock formation **106** together to produce the effect of an arch beam extending over the top of the tunnel in a manner shown schematically in FIG. **10**. In FIG. **10**, a group of bolts are shown installed along the dotted line axes which are generally radial to the curvature of the tunnel, but may vary considerably from this arrangement as suggested in FIG. **5**. The inside surface of the tunnel is indicated at **107**, and each bolt establishes a compression area from its point of application at the tunnel surface extending in a conical pattern at approximately 45° from the surface plate. These compression areas are shown defined in dotted lines in FIG. **10**. At the point where the compression areas of adjacent bolts overlap, the cross hatched area **108** is produced, in which all of the area is under the compression established by the bolt pattern. A similar condition exists at the opposite ends of the bolts. The presence of the cross hatched area causes the rock formation to function in the manner of a structural beam. The bolts not only establish the necessary compression to lock the laminae together for the transmission of shear forces, but the bolts also tend to prevent sections of the rock formation from falling away from the surface 107. This is further prevented, in most tunnel installations, by securing wire mesh across the exposed rock bolt ends, and securing it at the threading of the bolt rods outward of the retaining nuts. The wire mesh can be supplemented by a layer of plastering, if desired.

I claim:

1. A method of securing a rock formation in position, the said method including drilling a hole in said formation an installing a rock bolt assembly equipped with an anchor device in said hole, wherein the improvement comprises the following operations in sequence:

setting said anchor device;

steps for tensioning the said rock bolt assembly substantially up to a predetermined work load tension below the yield point of the bolt rod of said rock bolt assembly, said steps comprising, concomitantly applying tension to said bolt rod and elongating the same as a substantially linear function of the applied tension, increasing the applied tension and elongation of said bolt rod as a substantially linear function of increasing tension substantially to said work load tension, terminating the application of tension at a point short of and representing a substantial fraction of the yield point of said bolt rod, maintaining said last named tension on said bolt rod; and

grouting said rock bolt assembly in said hole to substantially fill said hole with grout around said bolt rod.

2. A method as defined in claim 1, wherein said grouting is delivered into said hole at the low end thereof via a conduit, and continued under pressure until grout is recirculated in said hole throughout the length of said rock bolt assembly.

3. A method as defined in claim 2, wherein the flow of liquid grout is subsequently plugged while in liquid form to permit the same to set under pressure in said hole.

4. A method as defined in claim 1, wherein said anchor device is set initially to an intensity sufficient to sustain said last named tension.

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