

July 7, 1964

C. I. WILLIAMS ETAL

3,139,730

ROCK ANCHOR

Filed Feb. 17, 1955

3 Sheets-Sheet 1

Fig. 1.

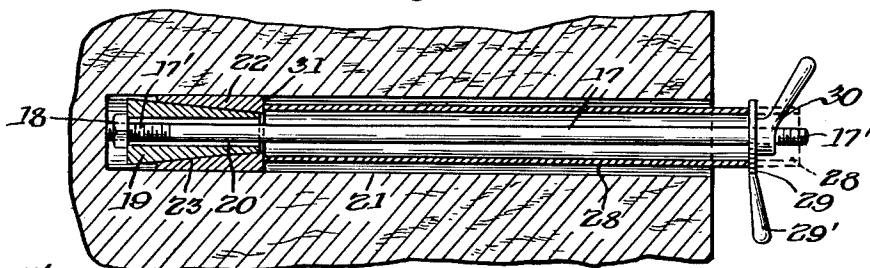


Fig. 2.

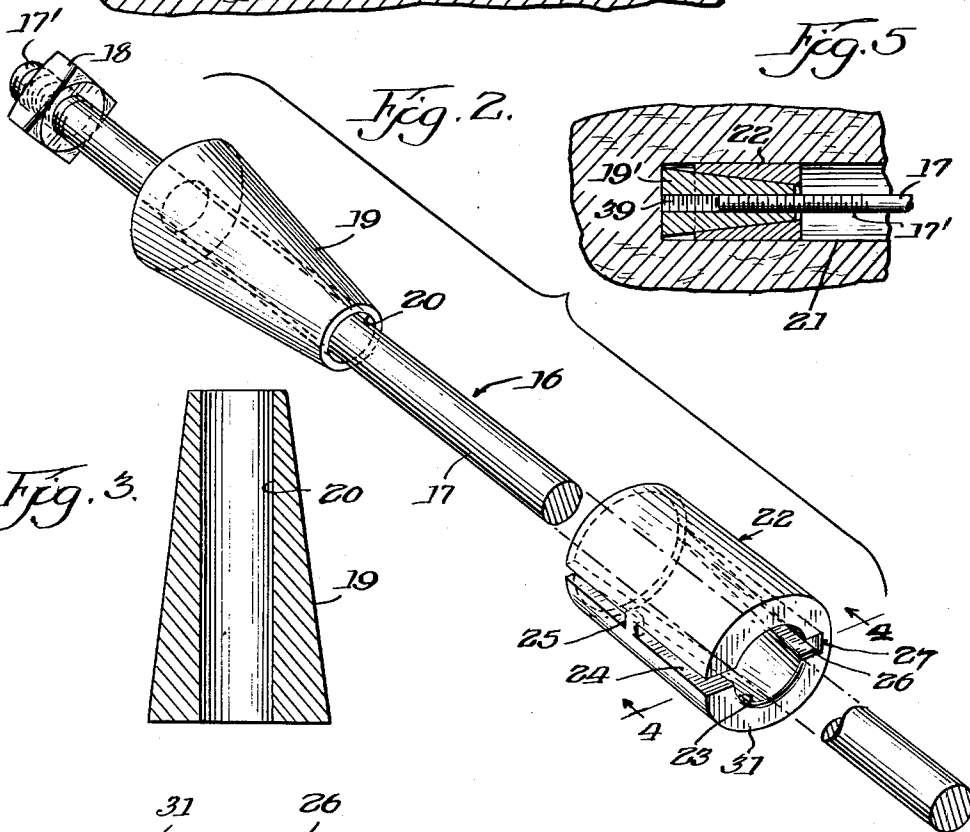


Fig. 5.

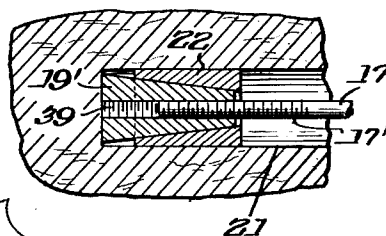


Fig. 3.

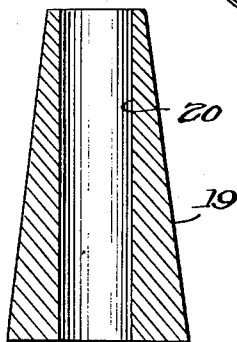
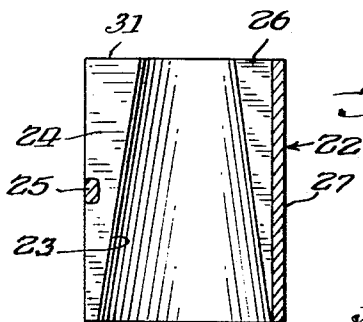


Fig. 4.



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July 7, 1964

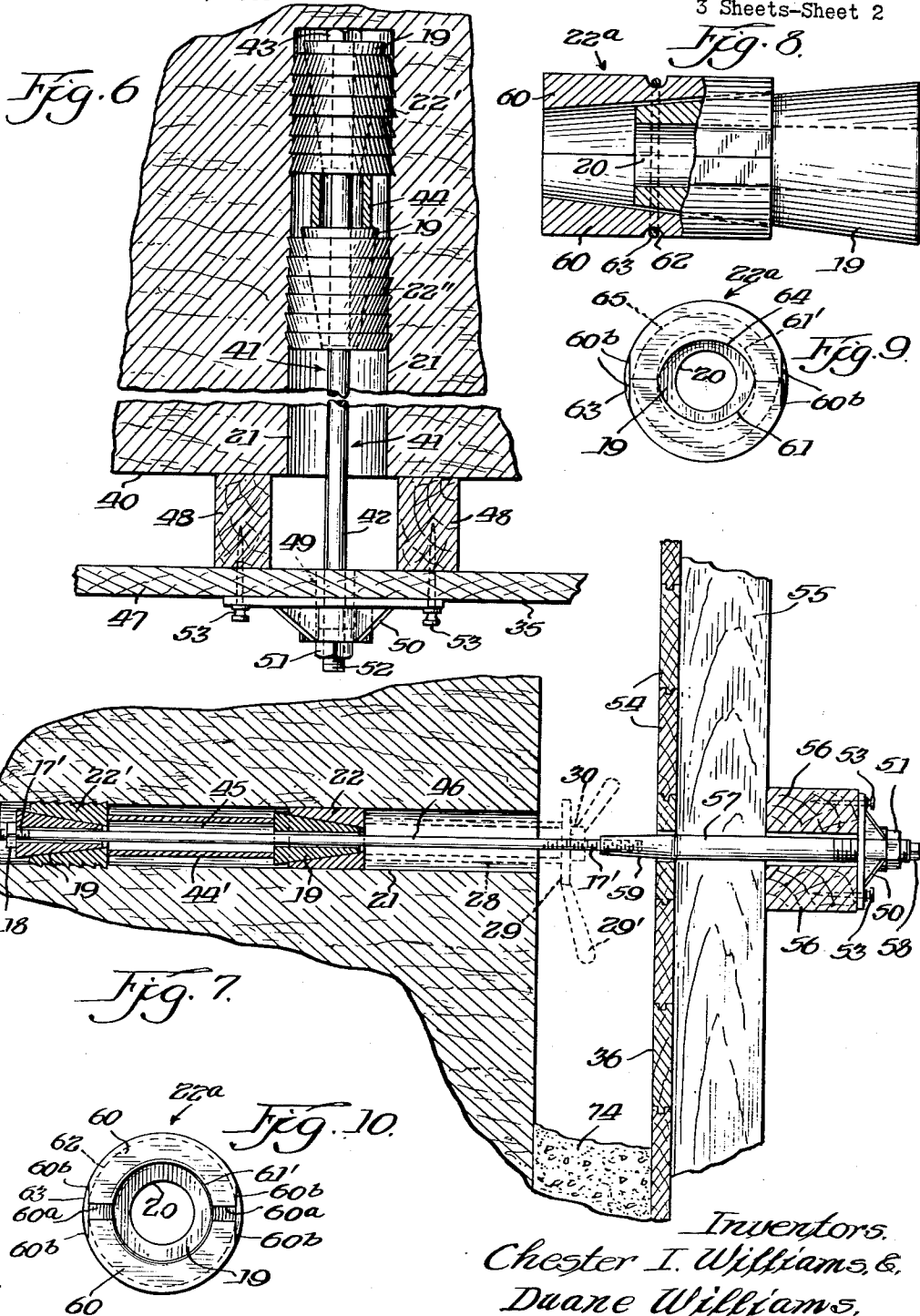
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ROCK ANCHOR

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3 Sheets-Sheet 2



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3,139,730

ROCK ANCHOR

Filed Feb. 17, 1955

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Fig. 11.

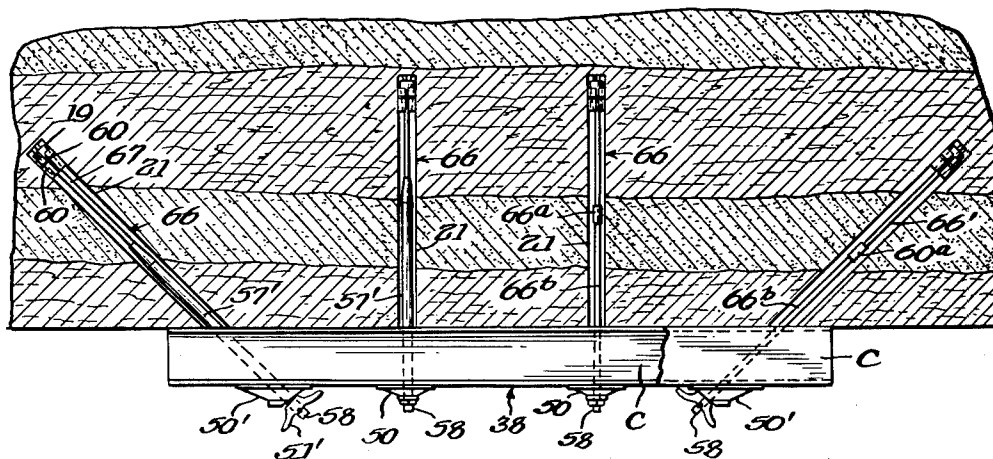


Fig. 12.

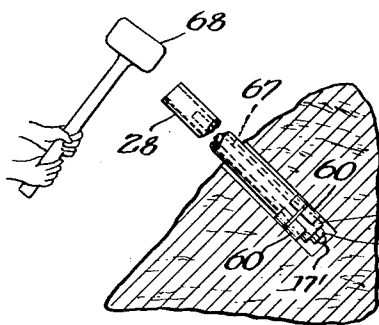
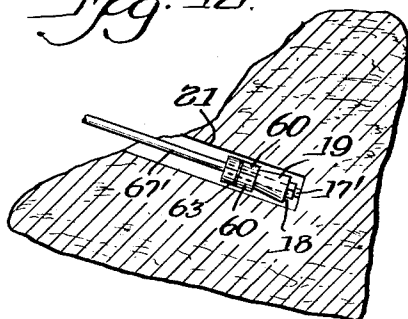
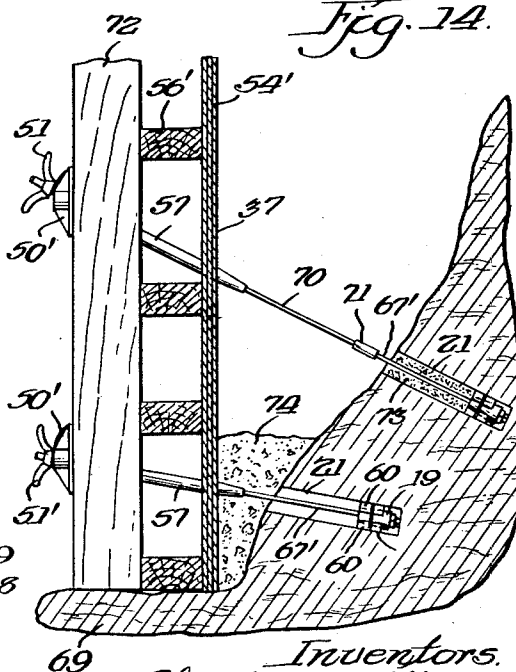


Fig. 13.

Fig. 14.



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3,139,730

ROCK ANCHOR

Chester I. Williams, 571 NE. Lombard St., Portland, Oreg., and Duane Williams, Boise, Idaho; said Duane Williams assignor to said Chester I. Williams.
Filed Feb. 17, 1955, Ser. No. 488,792
3 Claims. (Cl. 61—45)

This invention relates to concrete form constructions, and more particularly it relates to an improved form of rock anchor used in conjunction with the erecting of the forms, and also the use of rock anchors in the construction of tunnel forms and for roof stabilization by roof bolting, and for minimizing rock slides and the like uses.

The invention is particularly directed to the improvement in the rock anchor construction and the method of assembling the rock anchors in a geologic formation. The geologic formations with which the rock anchors are adapted for use may be consolidated or unconsolidated rock, large concreted mass of stony material which may be either natural formation or in the form of massive concrete constructions to which it is desired to affix forms thereto for pouring additional structures. The rock anchor construction of this invention is particularly adaptable for minimizing rock slides in rock cuts for roads or railway right of ways, and also for roof bolting operations for roof supports in tunnels used in mining to control the roof without the use of timbering, and for the prevention of accidents from falls of rock, coal, and the like in any mining operation.

Prior to our invention, when tying in forms to rock formations for the initial setting of the forms, it has been necessary to drill the holes for the anchoring devices and after they are in position cement them in place. Although entirely satisfactory under some conditions, it is necessary to wait for the concrete to set with a loss of time in pouring because of this delay. It is therefore a principal object of our invention to provide a form of rock anchor to which forms can be assembled, requiring no delay in the pouring of concrete because of the need for waiting for the concrete to set about the anchors.

Rock anchors have also been used prior to our invention incorporating mine roof bolts in which the end of the bolts are slotted to receive a wedge and, likewise, other forms as expansion shell assemblies with tapered plugs; and it is, therefore, another object of our invention to provide a rock anchor which is not only adapted for the erection of concrete forms but it is equally adapted for erecting tunnel lining and for mine roof bolting or to minimize rock slides.

Another object of the invention is to provide an improved rock anchor construction which develops substantially the strength of the tie rod and which can be readily installed by either skilled or unskilled workmen, using the conventional forms of drilling devices and the simplest forms of equipment for affixing the anchoring means within the stratum of concrete mass of stony material.

Still another object of the invention is to provide a rock anchor construction, using conventional clamping devices such as clamping brackets and she-bolt constructions used in conventional concrete form work, not only for the erection of concrete forms to the rock strata upon which the forms are erected but also in the mining industry as an accident prevention measure, and also as an improved means for increasing production and reducing costs in mining by eliminating the expensive timbering constructions.

Still another object of the invention is to use the improved rock anchor construction of this invention for the erection of tunnel linings in which the linings may be retained in place or detachably mounted after use.

Another object of the invention is to provide a rock

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anchor construction which may be assembled by impact or by screw tightening to the periphery of the hole in which it is mounted.

Still another object of the invention is to provide a rock anchor construction which may be erected in position, using hydraulic jacks or other hydraulically actuated lifting mechanisms which are available within tunnels used in mining operations.

Still another object of the invention is to provide a rock anchor construction which is simple in construction and economical to manufacture, and which will develop its maximum strength when used with various forms of tie rods used in concrete form construction or mine roof bolting.

Another object of the invention is to use a rock anchor with conventional concrete form constructions and hardware such as she-bolts, clamp brackets, and tie rods used in the erection of concrete forms and which are, likewise, equally adapted for mine roof bolting.

Still another object of the invention is an improved rock anchor construction using a split shell and solid cone which will develop maximum holding power, and in which the peripheral surface of the split shell may be plain or corrugated.

Still another object of the invention is the provision of simple tools for affixing the anchoring means including the split shell and cone to the periphery of a hole in which the anchoring means is to be assembled and affixed.

The invention also has among its objects the production of improved anchoring devices of the kind described and tools for assembling which are simple in construction, reliable, durable, economical, inexpensive, easily installed, and satisfactory for its purpose.

In order to accomplish the various objects of the invention, we have provided an improved fastening device or rock anchor construction incorporating an improved shell and cone construction for use with a tie rod wherein the anchoring means may be simply affixed to the periphery of a drilled hole to receive the anchoring means in either a concreted mass of stony material such as encountered in erecting large masses of concrete or in tunneling and, for example, types of rough strata including hard shale, sandstone, limestone, medium shale, soft wet shale, when constructing tunnels for mining or other purposes. In one embodiment, the rock anchor construction comprises a hollow shell constructed to readily split when a cone complementally formed to the interior of the shell is assembled in position over a tie rod by assembling the shell by either impacting or using pressure applied by simple tools or hydraulically applied pressures. In another embodiment of the invention, the strength of the rock anchor may be developed by the multiple use of the anchoring means including a complementally formed shell and cone construction, and the surface of the shell may be either plain or corrugated. In another embodiment of the invention, the shell may be formed in two separate halves which develop the maximum holding power as a cone forces the shell halves outwardly as the anchoring means is assembled in position over a tie rod or bolt construction, which afterwards is used to assemble concrete forms for pouring concrete or supporting linings for tunnels or for the erection of forms for the pouring of tunnel linings of concrete. In another embodiment of the invention, the rock anchor construction of this invention is adapted for use with plates for minimizing rock slides and for mine bolting and also for the assembly of mine roof ties of prefabricated section, or for the erection of mine roof channel sets and mine roof plates in roof bolting. In erecting the various embodiments of rock anchors, simple tools such as pipe and sledge hammers may be used or forms of hydraulic jacks and hydraulic equipment such as lift forks on trucks used in mining and in

tunneling. Another form of equipment used for assembling rock anchors in position may include pipe and wing type washer and nut operatively mounted on the tie rod for forcing the anchoring means of the rock anchor in position by a pipe or other tubular tool.

Many other objects and advantages of the construction herein shown and described will be obvious to those skilled in the art from the disclosure herein given.

To this end, our invention consists in the novel construction, arrangement and combination of parts herein shown and described, and more particularly pointed out in the claims.

Referring now to the accompanying drawings forming part of the specification:

FIG. 1 illustrates a view in side elevation taken through a rock anchor assembled in a rock mass, partly in section, illustrating the use of the rock anchor and simple tools for the assembly of the rock anchor and associated bolt or tie rod in position within a predetermined hole to receive the rock anchor;

FIG. 2 illustrates an exploded view of one form of rock anchor illustrating the cone and shell of the anchoring means assembled on a tie rod or bolt prior to assembly within a preformed hole to which the rock anchor is to be assembled;

FIG. 3 is a sectional view of the rock anchor cone;

FIG. 4 is a vertical sectional view of the rock anchor shell taken along line 4—4 of FIG. 2;

FIG. 5 illustrates another embodiment of a rock anchor in which the cone is threaded to receive a tie rod or bolt;

FIG. 6 illustrates the multiple use of rock anchors and in which the shell thereof is corrugated for assembling a tunnel lining to a side wall or roof of the tunnel in which the lining may be left in place or detached;

FIG. 7 illustrates another use of the rock anchor of this construction wherein the anchoring means may be used in multiples and the shells thereof may be either plain or corrugated, and to which there is assembled to the tie rod a concrete form or tunnel lining erected by the use of she-bolts and clamp brackets, and if used for the pouring of concrete for tunnel linings or facings the forms may be detached for reuse;

FIG. 8 illustrates another embodiment of the anchoring means of the rock anchor in which the shells of the anchoring means are symmetrically formed halves complementally formed to the periphery of the rock anchor cone;

FIG. 9 is an end view of the anchoring means of the rock anchor construction of FIG. 8;

FIG. 10 is an end elevation of the anchoring means of FIGS. 8 and 9 in which the shells are positioned with respect to the cone in their expanded position;

FIG. 11 illustrates a mine roof channel set showing a typical installation of a roof channel, partly in cross section, to a mine roof;

FIG. 12 illustrates a rock anchor construction of FIGS. 8, 9, and 10 in position prior to expanding the shells in their final position;

FIG. 13 illustrates the impact method of affixing rock anchors in position; and

FIG. 14 illustrates, partly in cross section, a concrete form construction held in its erected position with rock anchors of this invention.

Referring now more particularly to the drawings, an improved form of rock anchor construction 16 will be particularly described with reference to FIGS. 1 through 5. The rock anchor construction preferably comprises a bolt or tie rod 17 similarly threaded at opposite ends. A nut 18 for threadably receiving either end of the rod 17 is mounted at one end and there is placed on the rod 17 a cone member 19. The cone 19 is formed with a hole 20 through which the rod 17 may be freely inserted with the base of the cone abutting the nut 18 when positioned in the hole 21 in which the rock anchor is to be affixed. A cylindrical-shaped shell 22 is provided with a conical-

shaped hole 23 complementally formed to receive the cone member 19 as illustrated in FIG. 1. The shell 22 is so fabricated that as the shell is forced over the cone, the shell will split in half. This is accomplished by forming the shell with a slot 24 as shown in FIGS. 2 and 4 with a connecting spacer 25 integrally molded with the shell but of such cross section that when certain stress is placed on the shell, the shell will split and this splitting is further effected by forming the shell with the tapered slot 26 diametrically opposite the first slot and with the wall of the shell of reduced cross section as at 27, FIGS. 2 and 4, so that the shell when affixed in position as shown in FIG. 1 will be separated into its respective halves.

In order to assemble the rock anchor in position, the hole 21 is drilled in the rock or other concreted mass of stony material with a suitable form of rock drill, preferably one and one-half inches to one and five-eighth inches in diameter. The rod 17 with the nut 18 in position on the threaded end has the cone 19 and the shell 22 assembled as shown in FIG. 2, after which they are placed in the hole 21. In order to affix the anchoring means in position, a piece of pipe 28 or other tubular structure is positioned as shown in FIG. 1 over the rod 17 and a washer 29 formed with a handle 29' is then assembled in place, after which a tail nut or wing nut 30 is threaded on the rod, and as the handle 29' of the washer 29 is held with one hand the tail nut 30 is tightened by the handle thereof. As the pipe is moved inwardly, as the tail nut is tightened, it abuts the outer face 31 of the shell 22. As the tail nut is tightened to its final position with the pipe 28 and shell 22 as shown positioned with respect to the cone 19, the reduced portion 27 is split and the connecting spacer 25 is also separated from one or the other of the faces on the slot 24. This is made possible as the shell is preferably made of cast iron, or other suitable material may be used, and as cast iron has very little tensile strength and with the cross section of the portions 25 and 27 designed as illustrated, the shell very readily splits in half. As the nut may be still further tightened, the cone 19 forces the halves of the shell into the periphery of the drilled hole 21 in the rock. Depending upon the size of the tie rod and the load to be supported, the force applied to the rod may be predetermined, using either a torsion wrench or other suitable device, so that the rock anchors for a particular installation may be all similarly installed for a predetermined loading.

After the anchoring means has been affixed in place, the tail nut 30 may then be detached along with the washer 29 and the pipe 28, whereupon any structure which is desired to be assembled to the rock anchor may then be affixed in place. This structure may be either a tunnel lining 35 as shown in FIG. 6, concrete forms 36 as shown in the construction of FIG. 7, or concrete forms 37 erected as shown in FIG. 14. The rod anchors may also be used for the erection of mine roof channel constructions 38 as shown in FIG. 11.

Referring to FIG. 5, there is illustrated a modified form of rock anchor construction in which the rod anchor cone 19' is modified to receive a threaded end 17' of the tie rod or bolt 17. In this embodiment, the complementally formed hole 39 is threaded the full length of the cone to permit adjustment of the rod 17 with respect to the cone. In this embodiment, the shell 22 may be assembled within the hole 21 as previously described with respect to FIG. 1.

Referring to FIG. 6, there is illustrated an arrangement of rock anchor cones and shells for increasing the loading of the rock anchor with respect to the hole in which the anchoring devices are assembled. In this particular illustration, the rock anchor construction is primarily used for assembling a tunnel lining 35 either to a roof or side walls of a tunnel 40 schematically illustrated. In this embodiment, a rock anchor construction 41 comprises cones 19 and serrated shell constructions 22' and 22''. In this modified shell construction, the serrations can be

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arranged as illustrated so that as the shells are expanded the corrugations expand outwardly into the periphery of the hole 21 to give increased holding power to the rock anchor. Although it is preferred to corrugate the shell as illustrated in the inner shell 22', it is also within the scope of the invention that the serrations or corrugations may be reversed as illustrated by the outer shell 22'', FIG. 6. It has been found that by reversing the corrugations to that of the shell 22', FIG. 6, the holding power is increased because of the particles of rock falling into the grooves of the serrations, and any load on the rock anchor which might cause movement of the shells causes the particles to become further embedded thereby increasing the holding power.

In this embodiment, the rod is illustrated in the form of a bolt 42 of predetermined length, depending upon the depth of the hole for the particular stratum of the concreted mass of stony material to which the anchor is to be affixed. The innermost cone 19 abuts the head 43 of the bolt, after which is applied the first serrated shell 22'. A piece of pipe 44 of any predetermined length may be inserted between the outer face of the first shell and the inner face of the second cone 19 over which is positioned the shell 22''. It is preferably desirable to use an arrangement of this type wherein it has been found that the rock stratum is spaced with an intermediate layer of material having no holding power, although it is within the scope of the invention that two or more of these anchoring means may be mounted contiguous to one another but spaced apart in the same rock stratum.

When applied in this manner, the anchoring means may be assembled in position by the impact method to be described later, or the same method as described with reference to FIG. 1 but more particularly illustrated in FIG. 7 for securing multiple anchoring devices in the same hole 21 but spaced apart from one another.

Referring to FIG. 7, there is illustrated a rock anchor construction 45 similar to that described with reference to FIG. 6 with the exception that one of the anchoring devices has a corrugated shell 22' and the outermost shell 22 is formed with a smooth peripheral surface. In this embodiment, the rod 46 is threaded at each end as described with reference to the construction of FIG. 1 rather than as a bolt as described with reference to FIG. 6. The two sets of anchoring means including cone 19 and shell 22' and also cone 19 and shell 22 are spaced apart by a piece of steel pipe 44' of predetermined length, and the pipe 28 shown in dotted lines together with the washer 29 and tail nut 30 are affixed to the outer threaded end 17' of the rod 46 as previously described with reference to affixing the anchoring means of FIG. 1 in position. As the tail nut 30 is adjusted, the pipe 28 is moved inwardly and the first shell 22 is forced in position to the point at which the cones 19 and 22 are moved inwardly with the pipe 28 and the pipe 44' to position the shell 22' in its final expanded position against the periphery of the hole 21 formed in the rock stratum. Further turning of the tail nut 30 finally affixes each of the shells 22' and 22 in their final secured position wherein the shells, if they are solid as described with reference to the construction of FIGS. 1 through 4, are split in half to be forced outwardly into the periphery of the hole 21. The tail nut 30, the washer 29, and the pipe 28 may then be detached, after which the tunnel lining 35 may then be assembled as illustrated in FIG. 6.

The tunnel lining preferably comprises sheathing 47 affixed to supporting or waler members 48, which abut the upper face of the tunnel roof or faces of the tunnel wall, depending on which surface the lining is affixed. The bolt 42 extends through a hole 49 and is affixed to a clamp bracket 50. The clamp bracket may be of the type as disclosed and claimed in the co-pending application of Chester I. Williams, Serial No. 344,271, filed March 24, 1953, for Waler Rod Bracket, or in U.S. Letters Patent 2,659,125 granted November 17, 1953, to Chester I.

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Williams for Clamp Bracket, and also includes a nut 51 for detachably mounting the clamp bracket to the threaded end 52 of the bolt 42. If desired, the sheathing 35 may be suitably secured to waler members across the face of the tunnel by any form of securing means. The clamp bracket 50 may be secured to the sheathing and walers by double-headed nails 53.

Referring to FIG. 7, after the anchoring means has been affixed in position and the tightening device including the pipe 28, washer 29, and nut 30 has been removed, if it is desired to erect the concrete form construction 36 for pouring a tunnel lining such as used in pen stocks and other types of tunnels, the prefabricated form 36 comprising sheathing 54, studding 55, and waler members 56 may be affixed to the threaded end 17' of the rock anchor construction 45 by a tapered she-bolt 57 of the type as disclosed and claimed in the U.S. application of Chester I. Williams, Serial No. 233,853, filed January 27, 1951, for Method and Apparatus for Handling Forms, together with a clamp bracket 50 and adjusting nut 51 such as are well known to the trade as "Hex Lock," or as disclosed and claimed in the U.S. patent to Chester I. Williams, No. 2,048,151 granted July 21, 1936, for Concrete Form Appliances. The clamp bracket 50 may be detachably affixed to the waler members 56 by double-headed nails 53. In attaching the she-bolts 57 to the threaded end of the tie rod 46, the she-bolts are affixed in place by applying a wrench to the squared end 58. When firmly affixed to the tie rod 46, the clamp bracket is adjusted to position the face of the form 36, the distance from the face of the tunnel or other surface which is to be lined to be equal to that of the layer of concrete to be poured. After the concrete has been poured and set, the form 36 is removed by detaching the nails 53, after which the clamp bracket 50 may be removed or left in place so that the she-bolt may be rotated by a wrench applied to the squared end 58 to detach the she-bolts. The tapered end 59 of the she-bolt leaves a conical opening from the face of the concrete lining which can be grouted, if desired. Although it is preferred to detach the tightening device including the pipe 28, washer 29, and tail nut 30 from each rock anchor, there might be instances when it is desirable to maintain pressure on the anchoring means. The structure of the tightening device is relatively cheap so that it can be left in position, though it is preferably removed when it is desired to apply forms for pouring the concrete.

Referring to FIGS. 8, 9, and 10, there is illustrated another embodiment over the form of anchoring means described with reference to FIGS. 1 through 5. Whereas the structure of the anchoring means, FIGS. 1 through 6, is formed from cast iron, in this embodiment the cone 19 which is similar to that of the structure of FIG. 2 is also formed of cast iron. Whereas the shell 22 of FIG. 2 is formed from cast iron with a frangible cross section to split when pressure is applied to place the shell in position, the shell structure 22a of FIGS. 8 through 10 is formed in two symmetrical halves 60, preferably of aluminum. The shape of the halves 60 is such that when placed together as shown in FIGS. 8 and 9, the opening 61 formed by the two halves is out of round as shown in FIG. 9. However, in the expanded position of FIG. 10, the opening 61' forms a circle, the halves 60 being spaced apart by an axially extending opening 60a. The periphery of each half 60 is formed with an arcuate groove 62 to receive a rubber band 63 or other form of securing means such as twisted wire, but of such size that as the shell 22a is moved to take the position of FIG. 10 with respect to the conical member 19 to that of FIG. 10, there is no restriction of the member 60 so that the split halves may be expanded into the surface of the hole in which they are inserted for maximum holding power.

In the construction as shown with respect to the cone 19 and any of the embodiments, it is preferred to form the cone with a hole 20, $1\frac{1}{16}$ " in diameter, so that a $\frac{3}{8}$ ", $\frac{1}{2}$ ", or $\frac{1}{4}$ " tie rod or bolt may be used. When smaller

tie rods are used in a hole of this size, a washer may have to be used with the nut 18 or head 43 of the bolt to prevent the $\frac{1}{2}$ " nut or head of the bolt from pulling into the hole of the cone. It is also preferred to form the shell halves 60 with flush off faces 60b. For an anchoring device as disclosed with reference to FIGS. 8, 9, and 10, it is preferred to form the base diameter of the cone $1\frac{3}{8}$ " and the top diameter $\frac{7}{8}$ ", the overall length of the cone being $2\frac{1}{2}$ ". The shell 22a, in the closed position as shown in FIG. 9, is formed with an outer circumference having a $\frac{3}{4}$ " radius. The eccentric opening 64 is formed by a $\frac{7}{16}$ " radius so that in the open position thereof, FIG. 10, the hole 61' will be equivalent to a $\frac{7}{8}$ " diameter hole. The eccentric opening 65 at the opposite end is formed by a $\frac{5}{8}$ " radius so that in the open position as shown in FIG. 10, it corresponds to a $1\frac{1}{4}$ " diameter hole. The outside diameter of the shell is formed by a $\frac{3}{4}$ " radius so that in the expanded position, the shell corresponds to a $1\frac{1}{2}$ " diameter shell. The dimension across the flat faces of the shell halves is $1\frac{3}{8}$ ". The overall length of the shell is 2". A shell of this size is suitable for use with either a $1\frac{1}{2}$ " drilled hole or a $1\frac{3}{8}$ " drilled hole when the shell is expanded by using a tightening device as described with reference to FIGS. 1 and 7, or by the impact method as will be described later with respect to FIG. 13. It is also preferred with this particular form when fabricated from aluminum that all surfaces of the cone 19 and the inside of the shell complementary to the cone surface should be as smooth as possible to reduce the friction when the tightening device or the impact method is used for affixing the cone and shell in place. The exterior surface of the shell may be slightly rough such as found with the ordinary sand casting though it may be relatively smooth. Although the shell of the embodiment of FIGS. 8 through 10 is preferably fabricated as shown, it is also within the scope of the invention that the shell may be corrugated as illustrated in the shells used in the embodiment of FIGS. 6 and 7, or the corrugations may be reversed as shown in the shell 22", FIG. 6.

Referring to FIG. 11, there is illustrated a mine roof channel construction 38. This construction includes one or more rock anchor constructions 66 or 66', which are inserted in holes 21 drilled through overlying strata of a mine tunnel as schematically illustrated. The channel set or mine roof channel construction 38 may preferably comprise standard structural channels C placed back to back and spaced apart sufficient to receive a tapered she-bolt 57' similar to the type of she-bolt used in the erection of concrete forms, FIG. 7. It is not essential that the she-bolt shall be tapered but the use of a common form of she-bolt construction minimizes the cost since the she-bolts may be used for more than one purpose. Affixed to the inner end of each she-bolt 57' is a tie bolt 67 which is complementally threaded to the threaded end of the she-bolt. Although in this embodiment it is preferred to use a headed bolt, it is within the scope of the invention to use a tie rod 67', FIG. 12, as also commonly used in concrete construction in which a nut 18 is affixed to the threaded end 17'. However, before the she-bolt is affixed to the tie bolt, if a tie bolt is used, it is essential that the cone 19 shall be first positioned on the tie bolt. However, if a tie rod 67' is used, the tie rod can be affixed to the she-bolt and the cone 19 positioned over the threaded end 17' and the nut 18 mounted in position. In this embodiment, there is preferably illustrated the use of the anchoring means of FIGS. 8 through 10 using the split shell halves 60. These, in turn, with the rubber band 63 in place can be positioned over the cone by stretching them apart and inserting the cone in position, after which the assembled anchoring means including the cone 19, shell halves 60, and tie rod 21 can be inserted in position, for example, as illustrated in the drilled hole 21 of FIG. 12. A pipe 28 as shown in FIG. 13 can be inserted in position and a workman, using a sledge hammer 68, can drive the shell halves 60 and the cone 19 so that the

nut 18 and the free end of the threaded rod 67' are affixed within the hole with the nut 18 and the free end 17' of the tie rod bottomed as shown in FIG. 13. Further driving with a sledge separates the shell halves 60 on the cone 19 laterally to wedge into the rock stratum.

Although the method of affixing has been described with reference to FIG. 13, which substantially shows a similar construction to that of FIG. 14 for erecting forms, the method is equally applicable for overhead use. Usually, in mine work and tunnel constructions, the overhead rock anchors can be more easily applied using the tightening device of FIG. 1. Also operating in tunnels are hydraulic jacks for drilling which may be modified to force the pipe 28 to affix the anchoring means in position rather than the use of a sledge. Similarly, hydraulic lift trucks are sometimes operated in tunnels and the lifting device of the truck whether mechanical, hydraulic, or electric could be used to force the anchoring means in position. Although it is preferred to insert the anchoring means and tie rod in the hole and then affix the she-bolt to the tie rod, it is within the scope of the invention that a suitable length of pipe can be used to take care of the added length of the she-bolt when positioning the anchoring means. The she-bolts have a squared end 58 which can be used to tighten the she-bolts in position, after which a clamp bracket 50 may be placed in position and a wing nut 51' used for clamping the bracket in position against the outer faces of the channels C after they have been inserted in position. With the type of clamp bracket used, it is possible to position the rock anchors at any angular position as shown or at right angles, and the clamp brackets clamped in their adjusted position. By using the spaced channels, it is not necessary to use channels which are predrilled for the hole spacing or which require with the use of the channel, angular brackets to take care of the angular drilling which is usually at an angle of 45° or 60°.

If the mine roof bolting is temporary, the she-bolts 57' may be used as illustrated, otherwise it is more economical to use couplings 66a with tie rods 66b. Williams "Hex-Lock" brackets 50 may be used with either the tie rods or she-bolts when there is no angular adjustment. If there is angular adjustment Williams "Vibra-Lock" brackets 50' may be used. Tie rods cut and threaded to the correct length may also be used rather than coupling lengths together.

Although the rock anchor of this invention has been described with reference to the use of channels for mine bolting, the roof anchor as described with reference to FIG. 11 is equally applicable for roof bolting without the use of channels with the clamp brackets serving as roof plates. A distinct advantage of the clamp brackets when used as roof plates is that when a Williams "Hex-Lock" bracket 50, or Williams "Vibra-Lock" bracket 50', and nuts 51 or 51' are assembled, or a bracket construction as disclosed and claimed in the U.S. Patent No. 2,659,125 to Chester I. Williams for Clamp Bracket, granted November 17, 1953, it is easier to mount these in position on the threaded end of the she-bolt or ordinary mine bolt. The surface area of the plate is also such that sufficient support is had between the centers of the various mine roof bolts which have been set at a predetermined pattern or arrangement, depending upon the type of rock in which the bolting is used. The above construction for mine roof bolting and description is illustrative only and any roof bolting operations, using the roof anchor construction of this invention, should be carried out in accordance with the plans approved by representatives of the U.S. Bureau of Mines and the Department of Mines of individual states wherein the operation takes place.

Referring to FIGS. 12, 13, and 14, there has been illustrated the impact method of erecting the rock anchor for the concrete form 37. The tightening device as described with reference to FIG. 1 may also be similarly used. As illustrated in FIG. 14 for setting a form on a rock founda-

tion 69, suitable holes 21 are drilled, after which a tie rod and associated cone 19 and split halves of the shell 22a are inserted within the holes and securely affixed in place by the impact method of FIG. 13 or the tightening device of FIG. 1 or any other suitable manner of firmly anchoring the shell halves 60 to the periphery of the hole in the rock stratum. Tapered she-bolts 57 are then inserted through the form as illustrated and secured to the threaded outer end of the tie rod 67'. For the upper she-bolt, since the spacing is different, it is necessary to couple a she-bolt extension 70 to the she-bolt 67' by a coupling 71. The concrete form 37 is preferably fabricated of sheathing 54', which may be of plywood or planking affixed to walers 56', and the she-bolts are affixed to vertical members or strongbacks 72. The Williams "Vibra-Lock" clamp brackets 50' and wing nuts 51' are then assembled in place as is well understood in the concrete form art. Although it is preferred to assemble the rock anchors as illustrated without grouting, it is within the scope of the invention where additional holding power is needed to withstand the thrust of the poured concrete that grouting 73 may be tamped in place about the tie rod thoroughly filling the remainder of the drilled hole 21. After the forms are erected in place as illustrated in FIGS. 7 and 14, concrete 74 can be poured and puddled in place to the required height, after which the concrete, having set, the forms can be moved for pouring successive layers as disclosed and claimed in the co-pending U.S. application of Chester I. Williams, Serial No. 233,853, filed June 27, 1951 for Method and Apparatus for Handling Forms, and also as disclosed in another co-pending application of Chester I. Williams, U.S. application, Serial No. 323,528, filed December 2, 1952 for a Cantilever Form. Although it is preferred to use a simple form of clamp bracket 50 with either a nut 51 as shown in FIG. 7 or a wing nut 51' as shown in FIG. 14, one may also use an improved clamp bracket granted to Chester I. Williams, U.S. Patent 2,659,125 on November 17, 1953.

Referring to the structure of FIGS. 6 and 7, there are illustrated different structures for either securing a tunnel lining as in FIG. 6 or timber protection for the roofs of mines. It also might be desirable, depending upon the manner in which the tunnel is dug, to couple onto the anchor with a coupling and rod, for example, as shown in FIG. 14. If the timber structure is to be temporary, for example, to secure concrete lining to the anchor and rock as illustrated in FIG. 7 or even to support a temporary tunnel lining, it might be preferable to use a she-bolt attachment on the anchor to secure the temporary timbers as illustrated in FIG. 7. If it is desirable to secure the temporary timbers in this manner, it would also be within the scope of the invention to affix flat plates and a nut which may be in the form of roof plates or keyhole plates such as used for mine roof bolting for roof stabilization, or as used in minimizing rock slides so that the temporary tunnel lining may be removed and yet the tunnel faces so bolted as to minimize falling rock. Instead of using roof plates and keyhole roof plates, clamp brackets such as described with reference to the structure of FIG. 6 may be used or those as described with reference to FIG. 11 may also be used, and it is also within the scope of the invention that mine roof channel sets may be subsequently erected after the removal of the temporary tunnel lining as illustrated with respect to the construction of FIG. 11.

It is preferred to use tie rods of high tensile steel, and normally a 1/2" rod is the most standard for anchoring purposes which is the same as used for setting concrete forms on off-rock forms as illustrated in FIGS. 7 and 14. The shells for the anchoring means may be of cast iron and may be formed either with or without the conical-shaped rings as illustrated in FIGS. 6 and 7 for more friction. Although cast iron may be used, aluminum may be used as disclosed with reference to the shell construction of FIGS. 8, 9, and 10, or a softer type of outer shell may

be used such as formed from lead which will conform to the periphery of the drilled rock hole to increase the friction of the shell with respect to the hole.

The rock anchor construction such as disclosed with respect to FIGS. 1 through 5 and 6 through 10 provides a simple construction that will carry more than a five thousand pound load and yet which is economical to manufacture. Anchors as disclosed will carry loads from five thousand to fifty thousand pounds, the size varying, depending upon the size of anchor used for the load required. Anchors of this type may be made for rod sizes varying from 1/4" to 3/4" and loads varying from five thousand to thirty thousand pounds. It is also within the scope of the invention that when used for mine roof stabilization and tunnel construction or for minimizing rock slides, it is preferred to use bolts or tie rods of 3/4" and 1" diameter material either for full-cut or rolled threads. The bolts or rods may be either headed or unheaded though for mine roof bolting, it is preferred to use headed bolts or the brackets as described above; and when extensions are used, high tensile strength couplings are preferably used along with high tensile extension rods. Although she-bolts may be used with the tie rods or tie bolts, it is also within the scope of the invention to use couplings and extension rods as illustrated in FIGS. 11 and 14 and these, in turn, may also be used either with or without she-bolts.

Although clamp brackets such as used in concrete form construction have been disclosed for use with rock anchors in mine roof bolting and tunnel lining, it is also within the scope of the invention that the usual form of steel roof plates and keyhole roof plates may be used and, similarly, instead of the twin channel construction as illustrated in FIG. 11, it is within the scope of the invention that conventional mine roof ties may be used in conjunction with conventional forms of plate and angle washers of 45° or 60°.

It is believed that there has been disclosed a form of rock anchor construction which is effective for use in roof stabilization so that the roof layers of rock and the like material may be affixed to an upper stratum of sandstone or other solid layer of concrete mass of stony material such as sandstone or other rock formation. The rock anchors preferably should be installed immediately as the tunnel is cut and should be spaced in accordance with approved practice, and should be so placed as to prevent sagging of the exposed roof as the concrete is cut.

With rock anchor construction as disclosed when used with roof bolting, an effective accident-prevention structure is produced and production may be increased and cost reduced over conventional forms of timber. It is also an effective device for replacing old timbering and for increasing ventilation areaways over timbered structures. It is applicable not only for use with collieries for it is equally applicable for other types of ore mines and other mining operations and may equally be used in water tunnel projects, pen stocks, vehicular and railroad constructions. It is also effective for reducing rock slides along railroad and highway rights of way through the cuts therefor in mountainous areas. Other equally obvious advantages in safety and economy are had over the conventional forms of timbering.

Referring to FIGS. 1, 7, 12, and 13, there has been shown both a screw type method of wedging the rock anchors of our invention in place and the impact method of securing the anchor in place. The screw-up type method has been particularly disclosed with regard to the embodiments of FIGS. 1, 6, and 7 and is equally applicable to the anchoring means of FIGS. 8, 9, and 10. Although the impact method as illustrated in FIGS. 12 and 13 and described briefly with respect to these figures seems simple, there is actually a difference between an anchor that will stand the strength of high tensile rods as used and an anchor that will only come up to substantially fifty percent of the ultimate strength. The

principal reason for this advantage of the impact over the screw type "setting" or "prestressing" of the anchor is that fact that (1) one cannot subject as much pressure with a screw tightening device as one can with the impact system; (2) the impact system drives the shell solidly over the cone which is bottomed at the bottom of the drill hole, breaking off any minor extrusions of rock particles on the outside perimeter of the drilled hole so that the shell ends up in solid contact with the outside perimeter of the hole in the rock and is "prestressed" so that when the load is applied, there is no tendency for the anchor to creep as there normally would be with a screw-up type of anchor which cannot be fully "prestressed." Sufficient pressure of the screw-type adjustment cannot be applied to break off any of these particles of rock and place the outer shell solidly in compression with the perimeter of the hole. Any creeping of an anchor used for the purpose of securing a form is equivalent to using mild steel or something that will stretch and allow the form to give out which would have disastrous results. Therefore, an important feature of this invention is a "prestressed" rock anchor construction. By using high tensile steels having an elastic limit of eighty percent of ultimate instead of forty percent of ultimate as in the case of mild steels, this gives a solid connection all the way through. An anchor of the type as disclosed or any of its parts under high concrete pressures and stresses will not creep, stretch, or give in any manner that would permit the form to move out of position or its established alignment and thus create disastrous results upon pouring of concrete with forms used in massive concrete structures. It is thus possible to establish definite working loads within the elastic limits of the high tensile steel used. With this impact method one would not have a human element to contend with such as screw tightening of the anchors on a screw-up type of shell anchor construction in common usage that would permit creeping of the anchor. Although torque wrenches may be used to obtain better results and for maximum anchorage, the applied torque should be from one hundred and fifty to two hundred ft. lb. depending upon the size of tie rod, it is impossible to have contractors in the field use these as they are expensive and are easily carried off the job; (3) the impact method also has another advantage with the type of anchor of this invention, which though different from most anchors is not necessarily solidly screwed into the cone. FIG. 5 illustrates the method of showing a threaded cone which may be used in conjunction with the anchoring means of this invention for affixing a tie rod or bolt thereto. Although the construction of FIG. 1 is satisfactory in which a threaded nut is placed on the tie rod, this construction may leave the rod in a loose position due to the fact that in order to tighten the anchor, the cone must move forward and the nut and rod away from the bottom of the hole. With the impact method as shown in FIGS. 12 and 13, the hole, anchor and rod are driven solidly against the bottom of the hole and the rod and nut driven solidly enough that it does not turn when coupled thereon, whereas with the method of FIG. 1, the assembly may move away from the bottom of the hole $\frac{1}{4}$ " or $\frac{1}{2}$ " so there is play in the rod, and it may be loose enough so that it would necessitate holding of the rod in order to couple onto it for the outer tying units such as illustrated in FIGS. 7, 11, and 14; (4) There is also another advantage to the impact or pressure method of forcing the shell over the cone rather than the cone into the shell. In using these anchors in tunnel work for roof construction, it is possible to use a hydraulic or mechanically operated fork-type lift truck to exert pressure against the rod by using the lift of the truck, forcing it over the cone as one would using a sledge hammer as illustrated in FIG. 13. When using the lift fork of a lift truck or other form of hydraulic jack and the like, the shell of the anchor is driven solidly against the outer wall of the

rock, expanding it at the same time, so that it is affixed solidly in position. Using a lift truck, the pressure of the lift fork is the same or more than one may exert with a sledge hammer. Since the lift trucks are in tunnels for other purposes, it is more convenient than using the sledge hammer, especially for overhead placement of the rock anchors for mine roof bolting. With applicants' method, one would use the same system by having a piece of pipe extended from the fork of the lift truck to the shell of the anchoring means and forcing the shell in precisely the same manner as one would normally do with a heavy sledge hammer.

Although the rock anchor construction of this invention has been disclosed as having the cone made of cast iron, it is within the scope of the invention that this may be fabricated from cast steel or forged steel but, for economical reasons, cast iron is cheaper and has sufficient compressive strength for the purpose used. The outer shell has been disclosed as also being made from cast iron or frangible material or so formed that when erected in place, the shell will split substantially in half as it is telescoped with respect to the cone by either the impact or tensioning method of affixing the rock anchor in place. Although the shell has been disclosed as being made from either cast iron, aluminum or lead, it is preferred to use cast iron or preferably aluminum. If the outer shell is of soft lead material for the loads which this anchor will take, the soft lead would not be entirely satisfactory nor would it take the impact for driving and "prestressing" that a shell would take made from aluminum or cast iron. When cast iron is used it is possible to fabricate the shell as described with reference to FIGS. 1, 2, and 4 to be frangible in order to split in half in its final position when telescoped with respect to the cone. When harder aluminum is used, a solid shell would not be used as it would not expand sufficiently to "prestress" it, and therefore the aluminum shell is formed in halves as illustrated in FIGS. 8 through 10. It is also within the scope of the invention to use an aluminum shell which may be fabricated to split in half. It is also possible with the anchoring means described to use either a threaded cone for affixing the tie rod or the cone as described in which the tie rod or tie bolt is inserted as described with reference to FIGS. 1, 8, 6 and 7.

Using anchors of this type, tests have been run using $\frac{1}{2}$ " rods which broke, which meant that the anchor went to at least seventeen thousand pounds. Tests have also been run with larger rods which have reached twenty thousand or thirty thousand pounds and even up to thirty-five thousand pounds with tie rods of larger sizes such as $\frac{3}{8}$ " and $\frac{1}{2}$ ".

Although it is preferred to use for ordinary conditions, shells such as described with reference to the construction of FIGS. 8 through 10 which will work in a $1\frac{1}{2}$ " or $1\frac{3}{4}$ " drilled hole, and in which the cone may be used with $\frac{5}{8}$ ", $\frac{3}{4}$ ", or $\frac{1}{2}$ " tie rod, other corresponding sizes of shells may be used, depending upon the size of the drilled hole in the rock and the size of the rod to be used. The hole in the rock is drilled with suitable rock drills usually to a depth of about 4" less than the length of the tie rod or bolt but this may be varied and, if necessary, extension tie rods may be used, for example, as illustrated in FIG. 14. The tie rod or extension tie rods may use either cut or rolled threads but a rolled thread is usually preferred because of manufacturing costs and other qualities. If the rock anchor of this construction is used for reinforcing the rock formation, simple bar plates are used with hardened washers and the nuts may be either hex or square, and torque wrenches may be used to install the nuts after the rock anchor has been affixed in its drilled hole.

It is possible to use anchors of this type with drilled holes using $1\frac{1}{4}$ " or $1\frac{3}{8}$ " bits, though it is preferred to use this form of anchor with drilled holes $1\frac{1}{2}$ " in diameter. In drilling these holes, any machine capable of

drilling a hole may be used but as most bolting is overhead or at angles approaching the vertical stopper, drills are preferably used.

It is thus evident that there has been disclosed simple and inexpensive forms of rock anchor constructions and modifications thereof which may be used for either erecting concrete forms, tunnel linings, or for rock stabilization such as in cuts or in mine tunnels. The construction permits linings and the like to be permanently erected in place or detached, after which the roof may be stabilized. There has also been disclosed an economical and improved form of rock anchor construction including a shell and cone construction which is adapted for use with bolts or tie rods and with she-bolt constructions, and which may be affixed in place by an impact method or high pressures exerted by hydraulic means and the like or by other forms of tightening devices.

Furthermore, the improved rock anchor construction of this invention works equally well in any rock stratum which has sufficient holding power to support the loads for which the rock anchors are used, and are equally adaptable for setting off concrete forms in rock foundations. The rock anchors when used in concrete foundations permit greater salvage of the parts of the she-bolt construction and forms used therewith.

Having thus described our invention, it is obvious that various immaterial modifications may be made in the same without departing from the spirit of our invention; hence, we do not wish to be understood as limiting ourselves to the exact form, construction, arrangement and combination of parts herein shown and described, or uses mentioned.

What we claim as new and desire to secure by Letters Patent is:

1. The combination with a concreted mass of stony material in which a tunnel is formed, the concreted mass forming a portion of the peripheral surface of the tunnel and in which a drilled hole is provided, of a lining for the tunnel supported contiguous to the peripheral surface of the tunnel, said lining comprising sheathing spaced from the peripheral surface of the tunnel and water members affixed between the sheathing and the surface of the tunnel, and means for affixing the lining to the tunnel comprising a rock anchor construction comprising anchoring means operatively mounted on one end of an elongated securing means and inserted within the hole, said anchoring means comprising a plurality of spaced aluminum shells, each of said aluminum shells formed with substantially a conical opening and complementally formed to the drilled hole and including an axially reduced and frangibly formed cross-section at the periphery thereof, spaced cones complementally formed to the conical opening of the aluminum shells and operatively mounted within the aluminum shells and upon the elongated securing means, a tubular member for spacing the aluminum shells, said tubular member on one end abutting the outer end of the inner aluminum shell and at the other end abutting the inner end of the outer cone, each of said aluminum shells telescoped with respect to the cone whereby the aluminum shells are forced transversely and embedded partially within the contiguous periphery of the hole to that of the respective aluminum shells in which the anchoring means is positioned affixing the anchoring means, and clamping means operatively mounted on the outer free end of the elongated securing means for affixing the lining to the surface of the tunnel.

2. As an article of manufacture, anchoring means for a concreted mass of stony material in which a drilled hole is formed, said anchoring means comprising a tie rod, a cone-shaped member mounted at the inner end of the tie rod and abutting a securing means at the inner end of the tie rod, shell means complementally formed to the cone-shaped member, detachable tightening means comprising detachable tubular means abutting the outer peripheral face of the shell means and positioned axially with respect to the tie rod, washer means abutting the detachable tubular member, and detachable securing means complementally formed to the outer threaded end of the tie rod, said shell means and said detachable tubular member having a diameter less than that of the drilled hole whereby the anchoring means is adapted to be positioned within the drilled hole, and upon said operator-operated detachable securing means being axially moved with respect to the axis of the tie rod, the detachable tubular member forces the shell means into the contiguous peripheral wall of the drilled hole as the shell means is forced axially with respect to the cone-shaped member, and upon detachment of said detachable tightening means including said detachable securing means, the washer and the detachable tubular member, the tie rod is affixed within the drilled hole and supported by the cone-shaped member and shell means.

3. As an article of manufacture, anchoring means for a concreted mass of stony material in which a drilled hole is formed, said anchoring means comprising a tie rod, securing means formed at the inner end of the tie rod, a cone-shaped member through which the tie rod is positioned with the base of the cone-shaped member abutting the securing means, shell means complementally formed to the cone-shaped member and adapted to be moved axially with respect to the cone-shaped member and laterally thereof, a tubular member abutting the outer face of the shell member, another cone-shaped member positioned on the tie rod with the base thereof abutting the outer face of the tubular member, another shell member axially mounted with respect to the second cone-shaped member and adapted to move laterally thereof, and detachable means for applying pressure to the face of the outer shell whereby each of the shells are laterally affixed to the contiguous periphery of the drilled hole in which they are assembled as the shells are moved axially with respect to their respective cone-shaped members, and upon the detachable means for forcing the shells being removed the tie rod is supported within the drilled hole by the respective cone-shaped members and the contiguous shells.

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