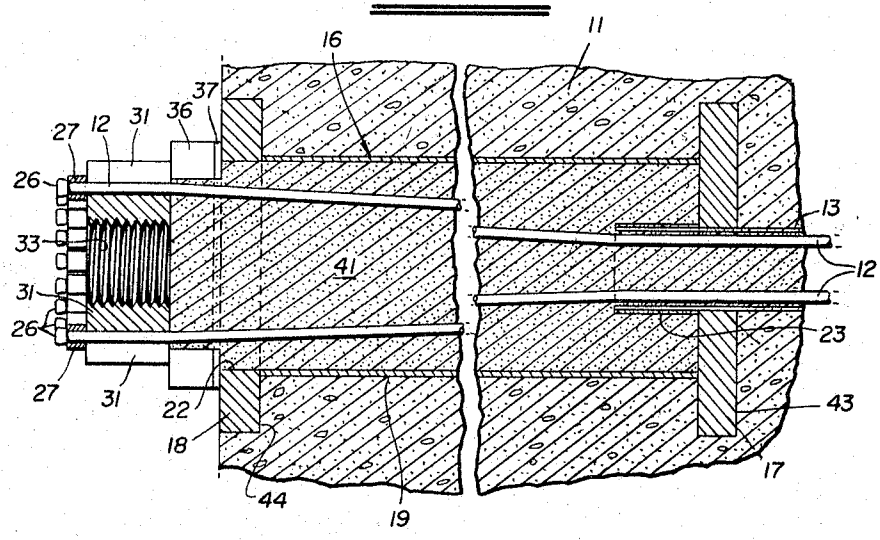
March 7, 1967 J. P. KOURKENE 3,307,310

APPARATUS AND METHOD FOR ANCHORING POST-TENSIONING TENDONS IN PRESTRESSED STRUCTURES

Filed Jan. 27, 1965 2 Sheets-Sheet 1

Fig. 1



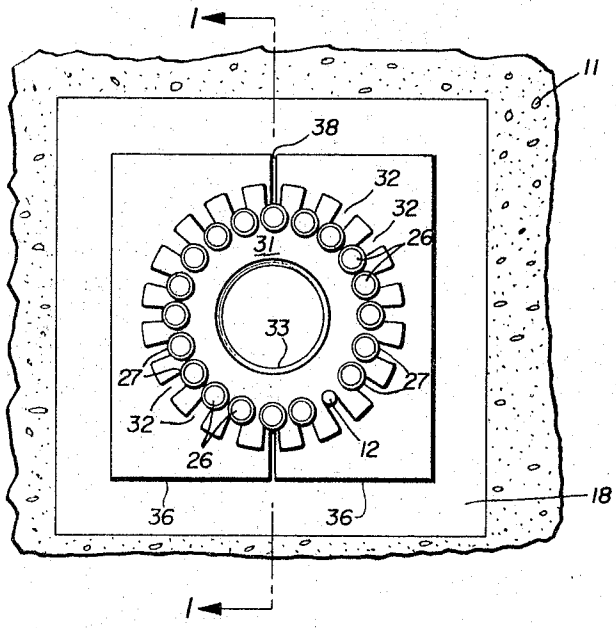


Fig. 2

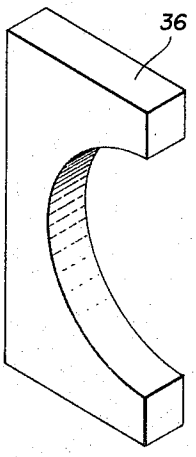


Fig. 3

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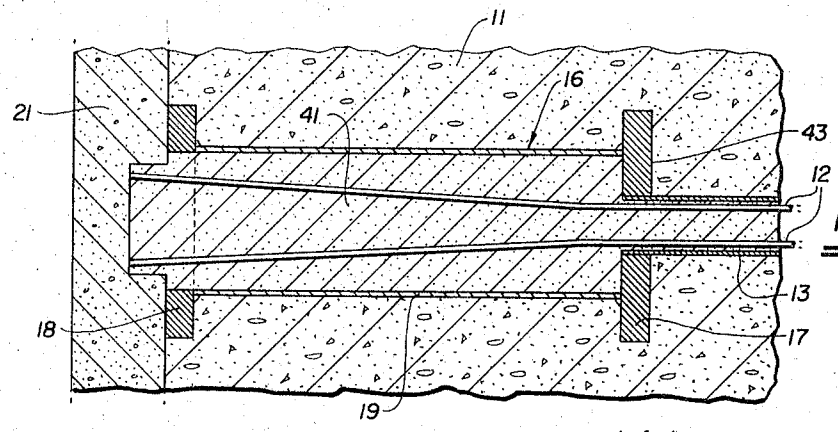


Fig. 4

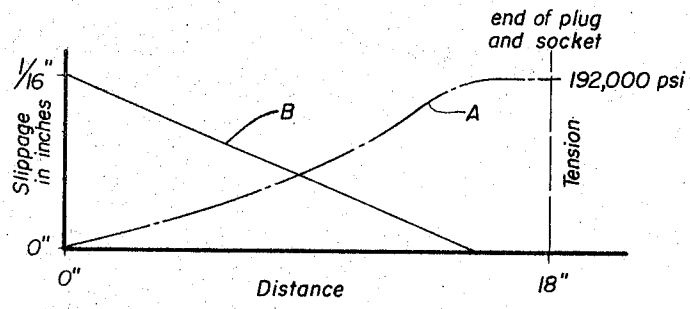


Fig. 5

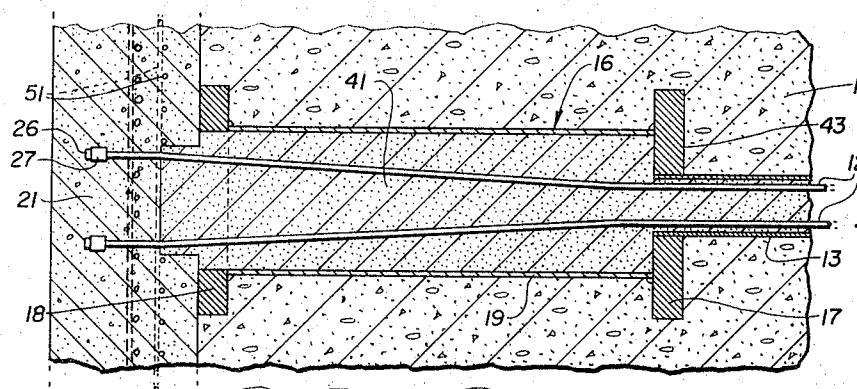


Fig. 6

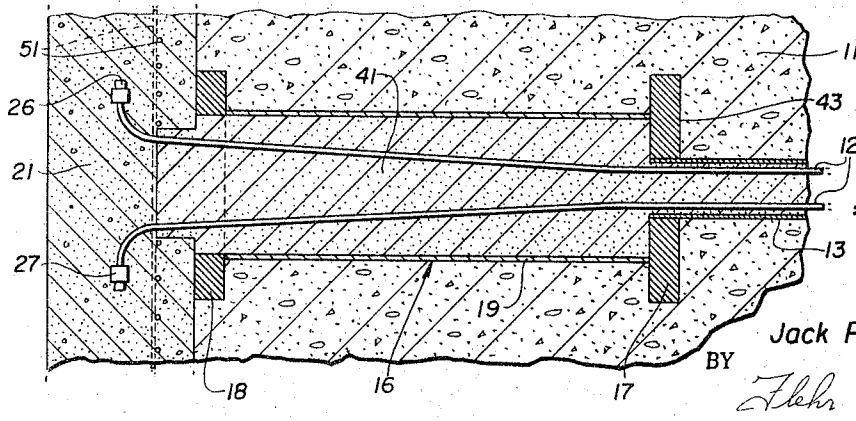


Fig. 7

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APPARATUS AND METHOD FOR ANCHORING POST-TENSIONING TENDONS IN PRESTRESSED STRUCTURES

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10 Claims. (Cl. 52—230)

This invention relates to apparatus for tensioning and anchoring post-tensioning tendons in prestressed structures.

As known in the art, the usual method for applying a post-tensioning force involves the use of special anchoring means which not only are used to tension the tendons but also serve as permanent members for transmitting the tension to the structure. These anchoring means generally use special metal parts together with anchoring members which are relatively expensive. As used, these anchoring means become permanently located in the completed prestressed structure, and thus they represent a non-recoverable item which substantially increases the cost of the structure. There is, therefore, a need for new and improved apparatus for post-tensioning and anchoring means.

It is therefore an object of the invention to provide apparatus for post-tensioning structures which will overcome the above named disadvantages.

Another object of the invention is to provide apparatus of the above character in which the functions of tensioning the tendons and that of anchoring the tendons in tensioned condition are carried out by separate means.

Another object of the invention is to provide apparatus of the above character in which the means for tensioning the tendons are recoverable.

Another object of the invention is to provide apparatus of the above character which does not rely solely upon the ends of the tendons or wedging thereof for permanent anchoring of the tensioned tendon.

Another object of the invention is to provide apparatus of the above character in which the means for transmitting the tension from the post-tensioning tendons to the structure by the use of pretensioned plug of grout.

Another object of the invention is to provide apparatus of the above character in which the fully compressed end of the plug is bound fast to the fully tensioned portion of tendons.

Another object of the invention is to provide an improved apparatus of the above character in which socket means forms a well for the plug to thus reduce or eliminate any materials extending beyond the end of the structure.

Another object of the invention is to provide apparatus of the above character in which secondary anchorage of the tendons is provided in the event the bond fails between the plug and tendons.

Another object of the invention is to provide apparatus of the above character in which a plurality of tendons are splayed to define a conical shape as they pass through the socket means to thereby act as additional wedge means for anchoring the tendons.

Another object of the invention is to provide apparatus of the above character in which the end portion of the tendons are secure in additional means for anchoring the tendons.

Additional objects and features of the invention will be apparent from the following description when read in conjunction with the accompanying drawings, of which:

FIGURE 1 is a vertical sectional view through a partially completed structure formed in accordance with the invention, and taken along the lines 1—1 of FIGURE 2.

FIGURE 2 is an end elevational view of the structure shown in FIGURE 1.

FIGURE 3 is a perspective view of a split shim for use in the invention.

FIGURE 4 shows a vertical cross-sectional view through a completed structure formed in accordance with the invention and showing the anchor plate, tendon ends, and shims removed.

FIGURE 5 is a graph showing the stress distribution in the anchoring plug and the slippage of the tendon as a function of distance from the end of the plug when constructed according to the invention.

FIGURE 6 shows an alternate complete structure in which the anchor plate is removed but the tendon ends and bushings are retained and secured in secondary means for anchoring the tendons.

FIGURE 7 shows another embodiment of the invention in which the tendon ends and bushings are retained, bent over and secured in secondary anchoring means.

Generally stated, my invention is directed to apparatus for prestressing structures by post-tensioning and utilizes a pretensioned anchor plug formed in situ. The pretensioned anchor plugs serves as permanent means for transmitting the tension from post-tensioning tendons to the structure to be prestressed.

Briefly, post-tensioning tendons are positioned through the structure to be stressed. A recess is formed at the end of the structure so that the tendons extend into the recess. Tension is applied to the tendons after which the recess is filled with grout which is allowed to set and cure. The applied tension is removed, along with the means for applying it, leaving a pretensioned anchor plug in the recess as the means for permanently transferring the tension from the tendons to the prestressed structure. In the preferred embodiment the recess is defined by a special socket.

In the form of the invention shown in the accompanying drawings, the invention is used to post-tension a concrete structure indicated generally by reference numeral **11** and partly shown. One end only of the structure **11** is illustrated, it being understood that the opposite end is essentially a duplicate. Tendons **12** as hereinafer described may be tensioned at the end shown in the accompanying drawings or the tendons may be tensioned at both ends. Accordingly, it is deemed unnecessary to illustrate the opposite end of the structure.

For preparation of post-tensioning and at the time the concrete forms (not shown) for the structure **11** are prepared and before the concrete is poured, a conduit **13** may be installed. The conduit **13** serves to maintain the tendons free for tensioning. The end of the conduit **13** extends into a recess **14** formed at the end of the structure.

A socket **16** is disposed in the recess **14**, and usually is mounted before pouring of the concrete for the structure **11** and thus also serves to define the recess **14**. The socket **16** serves as means for transferring various compressive and tensile forces during subsequent operations and also as a well for receiving grout to form the plug, as hereinafter described.

The socket **16** includes an inner plate **17** capable of transferring loads against the center of the structure **11** and an end plate member **18** in load transferring relationship with the end of the structure **11**. The members **17** and **18** are connected by tensile-compressive force transmitting means such as cylindrical tube **19** which is suitably fastened to each of the plates **17** and **18**, as by welding. The end plate **18** is provided with a hole **22** therein through which the tendons **12** pass.

The interior of the socket **16** is sufficiently long to enclose the desired length of grout to form the plug, and

is radially large enough to permit the tendons 12 to be spread out as they pass through the socket so that they do not conflict with each other in forming the plug, and so the tendons define a conical shape in one embodiment. A plurality of the tendons 12 is positioned through the conduit 13 and extend into the interior of the socket 16.

Suitable means is provided for post-tensioning each of the tendons 12 and consists of the apparatus as shown in detail in FIGURES 1–3. Generally, each of the tendons 12 is upset at its end to form a head or button 26 thereat. Prior to the forming of the button 26 on the ends of the tendons, hardened bushings 27 are installed, the bushings sliding snugly along the tendons. An anchor plate 31 is positioned exteriorally of the structure to be tensioned and of the socket 16 and the tendons slid into slots 32 in the plate 31 so that the heads 26 abut the bushings 27 which in turn abut the plate 31.

The hole 22 in plate 18 is sufficiently large that assembly of anchor plate 31, tendons and bushings, can also pass through it into the socket 16 so that a similar operation can be performed at the other end of the structure 11.

The anchor plate 31 is provided with a central passage way 33 adapted to receive a tensioning tool (not shown) and is tensioned thereby. After tensioning is complete, the anchor plate 31 is secured in place in space relation to the structure 11 and end plate 18 by one or more split shim pairs 36, 37 leaving an opening therebetween along the vertical line 38 to facilitate venting during subsequent grouting operations. For the detailed description of the anchor plate button and bushings shown, reference is made to my copending application Serial No. 206,644 filed July 2, 1962, wherein these means are described in detail.

After post-tensioning, the interior of the socket 16 is filled with grout by pumping the same therein through the opening 33 in the anchor plate 31. Various grouts to be described hereinafter can be utilized. As the grout sets and cures, it bonds itself to the socket 16 and to the tendons 12. Thus, the grout together with the tendons 12 form a unitary plug 41 in which the tendons 12 are firmly embedded. It is desirable for good bonding relation between the grout and tendons that the tendons be free of oil or other coating which might inhibit such bonding. After the grout has set and cured sufficiently, the shim pairs 36, 37 are removed and likewise the plate 31 is removed. Thus, the shim pairs 36, 37 and the plate 31 are reusable as tools. As shown in FIGURE 4, the tendon ends and bushings are also removed and the end of the structure given a layer of finishing concrete 21.

Upon removal of the anchor plate 31, as in FIGURE 4, the plate 31 no longer can serve to transmit the tension from the tendons 12 to the structure 11. The post-tension is now transmitted via the plug 41 of grout which is bonded within the socket 16. I have found that for very reasonable lengths of plug 41 the end of the plug abutting the inner plate 17 can be made completely pre-tensioned with no slippage of the tendons 12 thereat. Generally, the diameter of the tendons 12, the strength of bond between the grout and the tendons, and the length of the plug can be adjusted so that upon removal of the anchor plate 31 and consequent stressing of the plug, no slippage of the tendon occurs at the fully-stressed end of the plug adjacent the plate 17. For plain grout, not containing any particular special expanding properties upon setting up, the length of the matrix should be about 60 times the diameter of the tendon. For ¼ inch tendon this length is about 15 inches. Obviously, the socket 16 is sized to form the desired length of plug 41.

The length of the plug 41 and thus the length of the socket 16 may be shortened by using expanding grout to form the plug. Such an expanding grout may be compounded by the addition of calcium sulfo-aluminate component or a gypsum base powder or aluminum powder to the cement or by the use of self-stressing cement compounds. Other materials have proved very satisfactory and include an epoxy adhesive and epoxy mortar concrete, such as those which are formed from mixture of epoxy and sand in various proportions.

During the tensioning operation, the socket 16 acts to hold the shim pairs 36, 37 and thus anchor plate 31 in fixed relationship with respect to the structure. Since the face 43 of the inner bearing plate 17 and the face 44 of the end bearing plate 18 abut the structure 11, they also cooperate to resist forces exerted by the tensioned tendons 12, and member 19 acting to transmit a compressive force from end plate 18 to inner plate 17. After the applied tensioning members are removed, the tube 19 acts to transmit forces in tension from the inner plate 17 to the end plate 18.

For expanding grout, radial forces are set up which compresses the tendons and pushes outwardly against the walls of the socket 16 to thereby create a radial compressive stress and increase the bond between tendons 12 and the grout and thus decrease slippage therebetween. Upon removal of the tensioning means, slight slippage at the unstressed end of the plug occurs, while no slippage takes place at the inner stressed end of the plug. Thus, the tendons shorten slightly which, by Poisson's ratio, causes radial expansion of the tendons against the grout and thus even more securely bond the tendons and grout. And, the compression of the plug and restraint of the socket induces additional radial expansion of the plug on the tendons.

In one application the socket 16 was constructed of the following materials and dimensions: An inner plate 17 of steel approximately 7 inches square and ¾ inch thick having a central hole of diameter equal to that of the conduit 13 and a correspondingly dimensioned outer plate 18 spaced apart by a 5 inch diameter tube 19 which is welded to the plates 17 and 18 at each end to form a rigid structure. Tube 19 was about 1½ feet long and had a wall thickness of 3/16 of an inch. The outer plate 18 has a central hole equal to the inside diameter of the tube 19, which is large enough to pass the anchor plate 31.

Referring now to FIGURE 5, there is shown a graph "A" of the stress distribution in the tendon as a function of distance from the end of this structure after removal of the tensioning means. This graph is applicable to the completed structure such as are shown in FIGURES 4, 6, and 7. As shown, the stress in the plug is maximum possible near the end of the plug 41 abutting the inner plate 17 of the socket and reduces to zero near the outward end plate 18 of the plug. Also shown is a graph "B" indicating the slippage along the tendons in the plug after the applied tension is removed. The slippage is a maximum near the unstressed end of the plug and zero near the stressed end of the plug. Friction between the surface of the tendon and the concrete plug generates bond stresses that, integrated along the length of the tendon, build up the tensile stress in the tendon up to a maximum, near the inner plate 17, where no more slippage occurs.

In such structures as are discussed herein, it is generally desired to provide an absolutely safe mechanism which cannot fail under design loads in the lifetime of the structure. Thus, it is possible that a failure of the bond between the grout and the tendons could occur and the structure would no longer be stressed. To eliminate this possibility, I have inherently provided a structure which will prevent failure of the post-tensioning means. For example, if there is a failure in the bond between the plug material and the tendons, such failure is normally going to occur at the surface of the cone defined generally by the outer surface of the splayed tendons. Upon such failure, the tendons would nevertheless be held in place by the wedging action between the portion of the plug material within the cone and the portion without the cone.

Further precautions may be taken to supply added assurance that the failure can never occur and means to this end are provided as shown in FIGURES 6 and 7. As shown, the tendon ends and bushings are left intact after removal of the anchor plate.

Reinforcing **51** is then passed over the tendon ends and bushings and the end of the structure **11** covered with an additional layer of concrete which, when set, bonds itself to the ends of the tendons and bushings. Should the plug **41** and the cone action previously described fail, this additional layer of concrete will become structural, the tendon ends and bushings loading the additional layer. Where space or other factors dictate, the tendon ends can be bent over as shown in FIGURE 7.

Several advantages of the invention reside in the use of the socket **16** heretofore described. The end plate **18** closes off the socket and keeps the concrete of structure **11** from entering. The end plate **18** also transmits some of the prestressing load from the inner end of plug **41** to the end wall of structure **11**. Socket **16** also permits the anchor plate assembly to be manufactured and assembled independently of the tendons and to be installed at the time that the concrete forms are installed by carpenters; the tendons being installed by ironworkers at a later time.

Thus, I have provided a new and improved apparatus for permanently anchoring post-tensioned tendons to structures which utilizes a relatively inexpensive material in pre-tensioned form to act as the permanent means for transmitting the tensioning in the tendons to the structure. Further, I have provided novel socket which can transmit a portion of the load to the end wall of the prestressed structure.

While I have described my invention as embodied in a specific form and as operating in a specific manner for purposes of illustration, it should be understood that I do not limit my invention thereto, since various modifications will suggest themselves to those skilled in the art without departing from the spirit of my invention, the scope of which is set forth in the appended claims.

I claim:

1. In a prestressed structure, said structure having a plurality of tendons under post tensioning tension passing therethrough, socket means disposed in said structure to form a recess at one location therein, the tendons extending through said socket means, a force transmitting plug for coupling the tendons to the structure, said force transmitting plug comprising grout formed and set about portions of said tendons extending through said socket means so that a portion of said plug is in force coupling relation to said structure, said grout plug having a dimension along the tendons sufficient to form a permanent bond thereto, said plug serving to transmit tensioning forces from the tendons to the structure in such fashion that portions of the tendons closer to the structure are more securely bonded without any slippage in force coupling relation to the grout plug than are portions of the tendons farther away from the structure, said socket means serving to radially confine said grout plug so that when said plug is compressed by said tendons, the bond between the tendons and the plug is increased due to radial expansion of the tendons and the plug against the radially confining wall of said socket means, said tendons including untensioned portions extending beyond the grout plug and away from the structure, and means securing said untensioned portions extending beyond the plug so that upon failure of the bond between said plug and tendons, the tendons are still retained by said last named means.

2. A structure as in claim **1** in which the tendons are provided with headed ends and bushings slidably mounted on said tendons and abutting said ends so that additional holding forces can be exerted by said means securing the untensioned portions of said tendons.

3. A structure as in claim **1** in which the tendons are bent sideways where they extend beyond the prestressed plug.

4. In a prestressed structure having an aperture for the passage of post-tensioning tendons, socket means in communication with said aperture, said socket means forming an outwardly opening recess of greater radial dimension than said aperture, a plurality of tendons under post-tensioning tension passing through said aperture and at least part way through said recess, a force transmitting plug comprising grout formed and set about portions of said tendons passing through said recess and bonded to said tendons in such manner as to transmit the tension of said tendons to said socket means and thereby to said structure, portions of said tendons spaced from the aperture in said structure tending to be greater in diameter than portions of the tendons closer to the aperture in said structure, said greater diameter reflecting a degree of shortening and release of stresses in said spaced portion of the tendons due to slippage of the tendons within the grout, said greater diameter of the tendons serving to transmit at least a part of the tensioning forces to the plug to compress the same inwardly and radially outward against the socket means, thus increasing the bond strength between the tendons, the plug and the socket means.

5. A structure as in claim **4** in which said socket means includes an inner load bearing member capable of bearing loads against the direction of prestressing, an end plate member in load transferring relation with the end of the structure, and tensile force transmitting means connecting the inner load bearing member and the end plate member so that the post-tensioning force applied through the tendons to stress the plug act to load the inner load bearing member, which load is transmitted in part to the structure adjacent said inner member and transmitted in part by the tensile force transmitting member to the end plate member so that at least a part of the post-tensioning force is applied to the end of the structure.

6. A structure as in claim **4** in which said plug of grout is epoxy loaded cement.

7. A structure as in claim **4** in which said plug of grout is formed of cement which expands upon setting.

8. A concrete structure as in claim **4** in which said socket means includes a well portion having a bearing plate in contact with said structure and a cylindrical member, the cylindrical member serving to radially restrain said grout plug.

9. A structure as in claim **4** in which the tendons are splayed outwardly as they pass through the socket means, and thus define a conical wedge when set in said plug of grout.

10. A method for making a plug for coupling tension in a tendon to a structure for prestressing the same, comprising gripping the tendon with a removable anchor and applying a tension of a predetermined value to said tendon and anchor, disposing grout about a portion of said tendon under tension to form a plug having a dimension along the tendon sufficient to retain a permanent bond to a portion of the same after the applied tension is released and to assume force coupling relation to the structure, allowing said grout to set and form a permanent bond to the tendon, releasing the applied tension, and removing the anchor from the end of the tendon so that portions of the tendon away from the structure slip and become untensioned while portions of the tendon closer to the structure remain securely bonded in force coupling relation to the grout plug in such a manner that the portion of the tendon between the untensioned end and that bonded to the grout shrinks in elongation and thereby tends to increase in thickness to thereby increase the bond between the tendon and the grout plug.

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