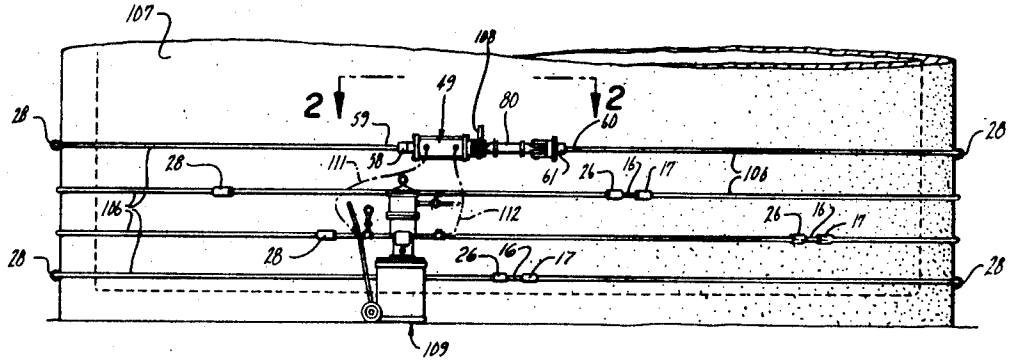
July 7, 1970 J. W. HOWLETT 3,518,748

CONCRETE PRESTRESSING METHOD

Original Filed Aug. 16, 1963 3 Sheets-Sheet 1

Fig. 1



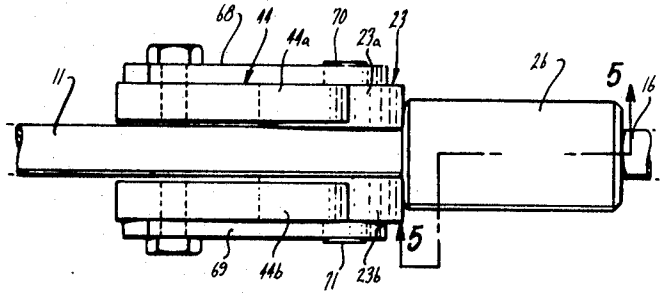


Fig. 3

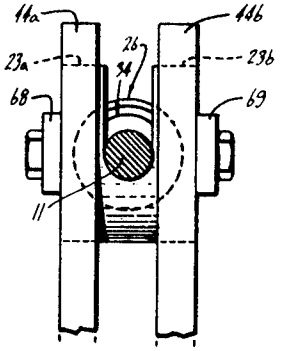


Fig. 4

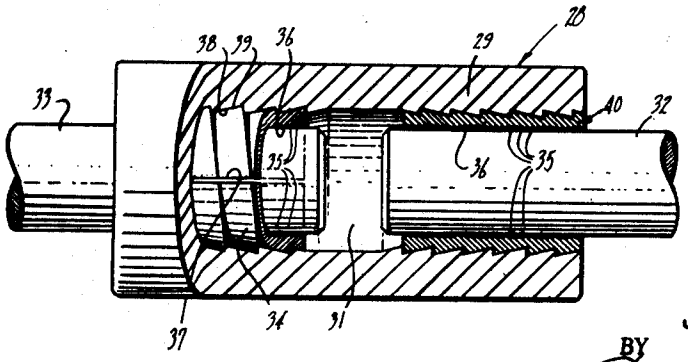


Fig. 5

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CONCRETE PRESTRESSING METHOD

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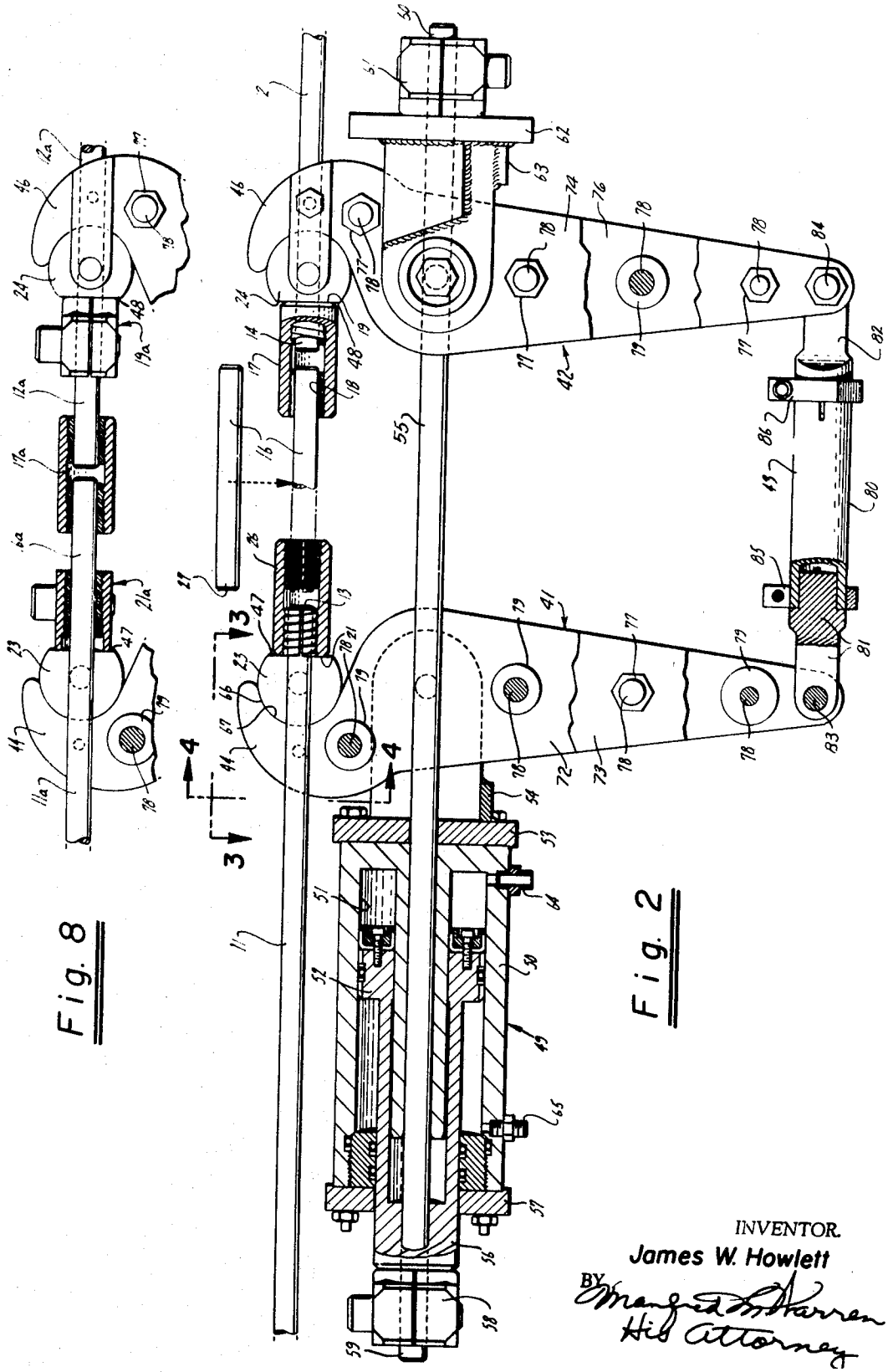


Fig. 8

Fig. 2

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July 7, 1970 J. W. HOWLETT 3,518,748

CONCRETE PRESTRESSING METHOD

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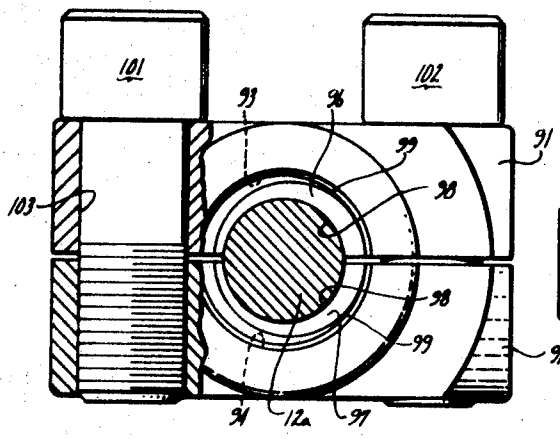


Fig. 11

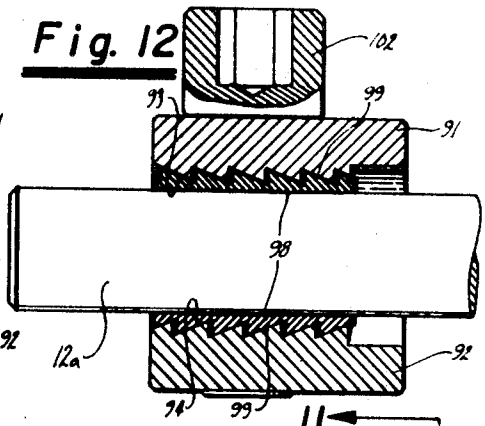


Fig. 12

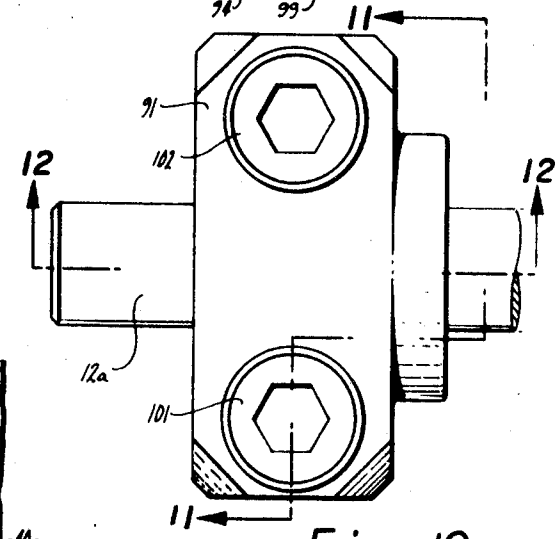


Fig. 10

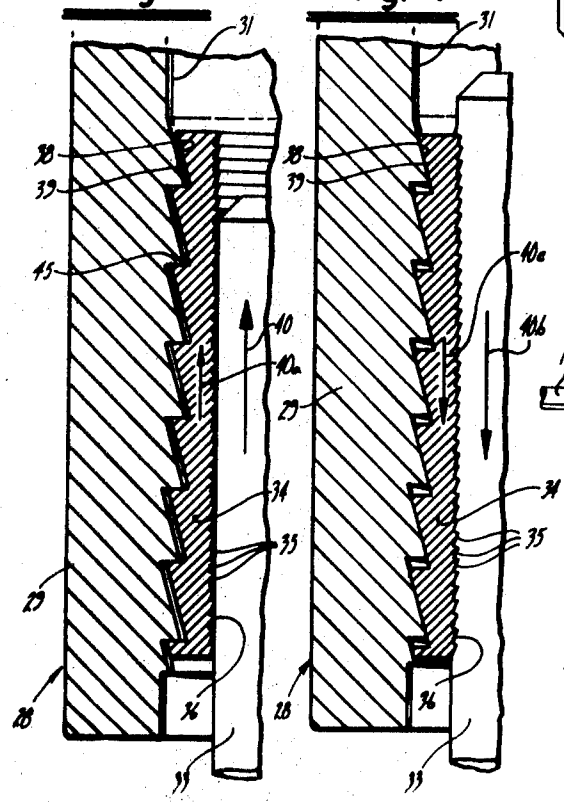


Fig. 6

Fig. 7

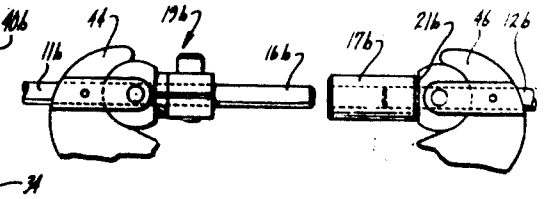


Fig. 9

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United States Patent Office 3,518,748 Patented July 7, 1970

3,518,748

CONCRETE PRESTRESSING METHOD

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Original application Aug. 16, 1963, Ser. No. 302,628, now Patent No. 3,343,808, dated Sept. 26, 1967. Divided and this application Apr. 12, 1967, Ser. No. 630,288
Int. Cl. B21d 39/00
U.S. Cl. 29—452 5 Claims

ABSTRACT OF THE DISCLOSURE

A method of drawing together and tensioning two generally aligned opposed ends of concrete prestressing tendons and securing these tendons is shown, which method enables very high tension forces to be achieved in the tendons. The method contemplates the use of a cam-acting, radially gripping, coupling member on the end of one tendon and a bar on the end of the other tendon which is grippingly engaged by the coupler as the bar is drawn into the coupler and which is held against withdrawal from the coupler. Also set forth are a jacking device and coupler construction suitable for use in the present method as well as method of tensioning tendons for construction of a concrete tank.

The invention relates generally to the art of prestressing various concrete structural members by the use of tensioning tendons such as wires, rods, stranded cables or bars, and more particularly to a tensioning method for drawing together and connecting two generally aligned end opposed tendons. This application is a division of application Ser. No. 302,628, filed Aug. 16, 1963, now Pat. No. 3,343,808, for Concrete Prestressing Apparatus and Method.

In various concrete prestressing operations, it is required that tension be applied to elongated tensioning tendons. This may involve either pretensioning or post-tensioning of such tendons in relation to the concrete to be prestressed. Some tensioning techniques involve securing a rod at one of its ends to a stationary object, and then pulling the rod from its other end and securing it with the rod under tension. In reinforcing large cylindrical tanks or the like, it has been common to wind wire or rods around the outer sidewall of the tank as a form of post-tensioning, which creates the desired radially inward prestressing forces. A disadvantage of the wire winding technique is that the wires are relatively small, and therefore are subject to corrosion and breakage whereby maintenance becomes a significant problem. The use of steel rods in prestressing tanks has generally involved two end opposed axially aligned rods secured at their remote ends, with means being provided for drawing together the adjacent ends of the rods to place them under tension. Heretofore this has been accomplished by the use of turnbuckles or similar devices involving threaded couplings. Aside from the tedious task of tightening a turnbuckle, this type of tensioning device is not capable of achieving the same high order of prestressing that can be withstood by modern special alloy steel rods. For example, rods are available that have a tension strength in excess of 100,000 pounds per square inch, and which can withstand tension forces much greater than that provided in practice by turnbuckle devices. Moreover, it has been found impractical to use coupling devices wherein threads are formed in the tensioned rods, inasmuch as the threads create weakened shear planes incapable of withstanding high tensile forces of the magnitude above mentioned. Another technique has been to provide heads or enlargements on the confronting ends of the tendons. These heads are then engaged by plates which may be drawn together by a hydraulic jack, after which bolts are mounted through the plates in connecting fashion and nuts run down on the bolts to hold the plates against separation upon subsequent release of the hydraulic jack. The plates and bolts thus form a holding frame or bracket for the tendons. While effective as a means for holding tendons under stress, the foregoing arrangement is relatively large and bulky, and considerably time consuming. Also, where center stressing of tendons is used in prestressed floor slabs, the foregoing arrangement may be too large and bulky for convenient use.

Briefly, the present invention comprises a method for engaging two adjacent ends of opposed tendons for drawing them together under tension and securely connecting them to maintain the tensioned condition. The apparatus used includes improvements on the wedge grip couplers of the type disclosed in Howlett Pat. No. 2,930,642, in addition to the apparatus for connecting and tensioning opposed tendons set forth in application Ser. No. 302,628, now Pat. No. 3,343,808, of which this is a divisional application.

Accordingly, it is a main object of the present invention to provide an improved method for tensioning rods by drawing together and connecting them, and whereby the rods can be placed under large tensile forces approaching their maximum tensile strength.

Another object is to provide a method of the character described for quickly, simply and efficiently connecting two spaced end opposed rods and placing them under high tensile stress.

A further object is to provide a method of the character described capable of prestressing circular tanks or the like by applying tension to rods disposed circumferentially around the tank's outer wall.

The invention possesses other objects and features of advantage, some of which of the foregoing will be set forth in the following description of the preferred form of the invention which is illustrated in the drawings accompanying and forming part of this specification. It is to be understood, however, that variations in the showing made by the said drawings and description may be adopted within the scope of the invention as set forth in the claims.

Referring to said drawings (three sheets):

FIG. 1 is a side elevation of a concrete tank depicting also the method of the present invention for post-tensioning encircling rods employed to prestress the tank.

FIG. 2 is a plan view, in an enlarged scale and partially cut away and in cross-section, of tensioning apparatus suitable for use in practicing the method of the present invention.

FIG. 3 is a fragmentary side view of a portion of the apparatus as suggested by the line 3—3 in FIG. 2.

FIG. 4 is a cross-sectional view taken substantially on the plane of line 4—4 of FIG. 2.

FIG. 5 is a cross-sectional view along plane 5—5 of FIG. 3 of a one-way wedge grip coupler suitable for use in practicing the method of the present invention, and operatively engaging two end opposed bar portions.

FIG. 6 is a fragmentary cross-sectional view on enlarged scale of the wedge member and coupler housing showing the position of the parts during the inserting of the rod tendon.

FIG. 7 is a view substantially the same as FIG. 6, but illustrating the coupler after the tendon has been placed under tension and is secured by the wedge member.

FIG. 8 is a fragmentary plan view partially cut away and in cross-section, similar to FIG. 2, but depicting tensioning apparatus forming an alternative embodiment of the invention.

FIG. 9 is a fragmentary plan view similar to FIGS. 2 and 8, depicting another alternative embodiment suit-

able for use in practicing the method of the present invention.

FIG. 10 is a side view of a wedge grip nut shown in the embodiment of FIGS. 8 and 9.

FIG. 11 is a cross-sectional transverse view taken along the planes suggested by the line **11**—**11** in FIG. 10.

FIG. 12 is a cross-sectional view taken along the axis of the bar member shown in FIG. 10, and is suggested by the line **12**—**12** as shown in FIG. 10.

Referring now to the drawings, the apparatus illustrated provides means for drawing together and tensioning two generally aligned tendons **11** and **12** having opposed spaced ends **13** and **14**, and includes a bar member **16**; at least one coupler member **17** having gripping means **18** for axially receiving the bar member **16** and holding it against return movement; one of the members **16** and **17** being mounted on the tendon **11** in opposed confronting relation to the tendon **12**; means for mounting the other of said members **16** ad **17** on the tendon **11** in position for operative engagement with the member on the tendon **12**; jack engaging means **19** and **21** provided respectively on each said tendon **11** and **12**; and jacking means including jaws **23** and **24** for engaging the jack engaging means **19** and **21** for forcing the tendons **11** and **12** toward one another and operatively connecting the members **16** and **17** together, whereby the jacking means can be released to leave the tendons and members under tension.

In the embodiment of the invention depicted in FIGS. 1–7, and in particular FIG. 2, the means for mounting the bar **16** on the tendon **11** includes a second coupler **26** mounted on the tendon **11** and adapted to receive the end **27** of the bar member **16** in the same manner as does the coupler **17**. The remote end shoulders of the couplers **17** and **26** are seen in this embodiment to provide the aforesaid jack engaging means **19** and **21**, and the jaws **23** and **24** engage these shoulders to draw the tendons together.

As more specifically regards the structure of the couplers **17** and **26**, reference is made to FIGS. 5–7 wherein a coupler **28** is illustrated and includes a housing **29** having an interior bore **31** for receipt of bar ends **32** and **33** to be connected. A sleeve-like wedge member **34** comprises the aforesaid gripping means **18** and is dimensioned to fit around the end **33**, with an internal diameter having an interference fit therewith. The wedge **34** has an inner surface **36** formed with teeth **35** for biting into and gripping the bar **33**, and has a single longitudinal slit **37** to enable radial expansion and compression against the bar. A plurality of longitudinally spaced annular inclined and interfitting cam planes **38** and **39** are formed respectively on the wall of the bore **31** and the external wall of the wedge **34**, whereby axial pull on the bar is translated into radially internal gripping forces of the wedge teeth on the bar. In this regard, the interference fit between the bar and inner surface **36** provides an initial grip to start the cam action. The inclined and interfitting cam planes **38** and **39** are preferably formed as mating spiral threads, with the sleeve-like wedge member **34** thus being adopted to be threaded longitudinally in and out of the bore **31**. To accommodate the bar **32**, another wedge **40**, similar to the wedge **34**, is mounted in generally the same manner at the other end of the bore **31**.

As an important feature of the present construction, and as above noted, an interference fit is provided between the respective bar and wedge members. More specifically, the external diameter of bar ends **32** and **33** is slightly greater than the normal unstressed internal diameter of the wedge sleeves **34** and **40** so that the axial insertion of the bar ends cause a resilient expansion of the wedge sleeves and a compressive gripping of the bar peripheries by the teeth **35** provided on the internal surfaces **36** of the wedge sleeves. To provide for such resilient expansion of the wedge sleeves **34** and

40, the normal unstressed external diameter of the wedge sleeves at cam planes **39** is less than the internal diameter of mating cam planes **38** provided on the internal wall of the housing. There is thus provided an important radial clearance between the wedge sleeve and the housing when the bar end, such as end **33** of FIG. 6 is inserted axially into the wedge sleeve as depicted by arrow **40**. The interference fit between the bar end and wedge sleeve, as aforementioned, causes wedge sleeve **34** to be displaced internally, as depicted by arrow **40***a*, by the movement of the bar end **33** until the shoulders **45** at the axial ends of the spiral segments defining the mating cam planes **38** and **39** move into abutment as illustrated in FIG. 6. In this position of the parts, a small radial clearance between the wedge sleeve and the housing will still exist to provide manufacturing tolerance and proper functioning of the device. When return tension is placed on bar **33**, however, the bar moves in a reverse direction as depicted by arrow **40***b* in FIG. 7; and this return movement of the bar carries with it the surrounding wedge sleeve **34**, as depicted by arrow **40***c*. The latter movement of the wedge sleeve closes the clearance between the mating cam planes and the wedging, camming action of the wedge sleeve against the bar **33** sinking teeth **35** into the periphery of the bar and securely gripping the latter with great holding force.

The method of the present invention in broad terms consists in the steps of mounting the coupler member **17** on the tendon **12** and providing the bar member **16** on the end of the tendon **11**, which in the embodiment depicted in FIG. 2 involves the provision of a coupler **26** secured to the tendon **11** and adapted to grippingly receive the end **27** of the bar **16**. Force is applied by the jacking means to urge the tendons together and to bring the couplers **17** and **26** into gripping connecting engagement with the bar **16**. In the embodiment depicted in FIG. 2, the bar **16** is initially placed between the couplers **17** and **26** in spaced relation therewith, after which the couplers are drawn together into engagement with the respective ends of the bar. The force of the jacking means is then slowly released thereby enabling the bar to be gripped securely by the coupler wedges. It is noted that the tension initially provided by the jacking means is diminished after the force is released and as the teeth of the wedges bite into the bar. More specifically, as the teeth bite radially into the bar, there is a longitudinal displacement of the wedge relative to the coupler bore, which occurs primarily from the relative movement of the aforesaid interfitting cam planes of the wedge and housing bore. This relative movement is indicated by comparing FIG. 6, showing the coupler as the bar is being inserted, and FIG. 7 showing the coupler when the bar is under tension, it being observed that coupler is moved to the right relative to its position in FIG. 6.

In order to achieve a maximum tension in the rods, it is frequently desirable to remove the slack created by the aforesaid setting of the wedges. In the embodiment depicted in FIG. 2 this is accomplished by applying force to the couplers by the jacking means a second time, whereupon the tensile forces in the bar **16** are substantially eliminated, leaving it in an unstressed slack condition. By substantially taking up the slack in the bar **16**, the force of the jacking means again can be released to leave the rods at the desired tension. With regard to the step of taking up the slack in the bar **16**, it will be recalled that the wedge of each coupler has its cam surfaces formed into a spiral thread configuration, whereby rotation of the sleeve member moves it longitudinally relative to the coupler housing. By providing the sleeve members of the two couplers **17** and **26** with oppositely wound threads, the bar **16** when in slack condition can be rotated about its axis in a direction pulling the opposed bar ends tightly into the two couplers. Then, after the force of the jaws is released there is virtually no

further longitudinal movement of the interfitting cam planes of the couplers, whereby the rods are maintained at substantially the tension achieved by the second application of force. While the rotation of the bar **16** is similar to taking up slack with a turnbuckle, there is no axial tension force on the bar as the slack is taken up. Rather, the rods are maintained in a tensioned condition by the jaws of the jacking means.

It will be appreciated that the couplers **17** and **26** can be provided on tendons of varying types, such as stranded cables, rods and the like. As shown in the embodiment of FIG. 2, these couplers each are of the double-ended type described more fully with regard to FIG. 5, and thus are adapted to engage a rod tendon in the manner described. It will be appreciated, however, that single-ended couplers could be used by welding or otherwise securing them to the tendons, be it a rod, cable or other configuration.

With more detail now regarding the aforesaid jacking means, there are provided a pair of arms **41** and **42** mounted on a link member **43** for pivotal movement relative to one another and having free ends **44** and **46**. The aforesaid jaws **23** and **24** are mounted respectively on the ends **44** and **46**, and each have bearing surfaces **47** and **48** for engaging the corresponding couplers **17** and **26** in the apparatus of FIG. 2. Fluid pressure means **49** is connected to draw the arms together whereby the couplers **17** and **26** can be moved into engagement with the connecting bar **16** as previously described. The fluid pressure means **49**, as best seen in FIG. 2, is of generally conventional construction and consists of a housing **50** providing an interior cylinder **51** within which is mounted for reciprocation a piston **52**. One end **53** of the housing is attached by a bracket **54** to arm **41**, which the piston **52** is connected to the other arm **42** by a rod **55** which here projects axially through the housing **50** and piston **52** so as to project from a piston shaft section **56** which extends through the opposite end **57** of the cylinder housing. A wedge grip nut **58**, to be described more fully hereinafter, forms a protuberance on the outer end **59** of the rod **55** so as to bear against the adjacent end of piston shaft section **56**. The opposite end **60** of the rod **55** may be similarly connected to the arm **42** by a wedge grip nut **61** which is arranged to bear against a flange **62** provided on a mounting bracket **63** fixed to the arm **42**. Preferably, the mounting brackets **54** and **63** are U-shape and are pivotally secured to arms **41** and **42** as illustrated. Housing **50** is here provided with inlet and outlet fittings **64** and **65** located adjacent the opposite ends **53** and **57** of the cylinder for conveying fluid under pressure into and out of the cylinder. As will be observed, the introduction of fluid under pressure into inlet fitting **64** will cause a displacement of piston **52** to the left, as seen in FIG. 2, thus effecting a closing of the arms **41** and **42** and jaws **23** and **24**. Contrariwise, the admission of fluid into the cylinder by way of fitting **65** and the withdrawal of fluid by way of fitting **64** will permit a displacement of piston **52** to the right, as seen in the drawing, and an opening of the arms and jaws. It will be noted that the rod **55** is disposed intermediate the link **43** and the free ends of the arms **41** and **42**, and is substantially parallel to the link **43**. The rod **55** is seen to be movable relative to the arm **41**.

In further describing the arms and jaws of the jacking means, it will be appreciated that the two arms are symmetrical and substantially identical to one another. Thus, reference is made now only to the arm **41** and jaw **23** mounted thereon. In particular, it is preferred that the free end **44** of the arm **41** includes a pair of bifurcated elements **44***a* and **44***b* adapted to fit around the corresponding tendon **11**, as is shown in detail in FIGS. 3 and 4. Similarly, the jaw **23** also includes a pair of bifurcated elements **23***a* and **23***b* which fit around the tendon **11**, and are in general alignment with the elements **44***a* and **44***b*. As shown, the elements **23***a* and **23***b* are spaced closer together than the elements **44***a* and **44***b*, whereby the tendon **11** fits snugly into the jaw while being able to pass relatively freely into the opening of the arm. In order to assure a firm grip of the couplers by the jaws, each jaw is pivotally mounted on its respective arm whereby the jaw and coupler need not move relative to one another as the arms are drawn together. Furthermore, in order to withstand the high forces involved in tensioning rods with the instant apparatus, the jaw **23** and free end **44** respectively have complementary arcuate bearing surfaces **66** and **67**. In this manner, pivotal movement of the jaw relative to the arm is allowed but while still providing a sufficient bearing surface between these two members to transmit high force from the arms through the jaws to the couplers and rods. Preferably, the surface **66** is convex and is complementary to the concave surface **67**. A pair of strap-like members **68** and **69**, secured rigidly to the elements **44***a* and **44***b*, pivotally support the jaw **23** by means of stub shafts **70** and **71**, but because of the arcuate bearing surfaces these stub shafts need not support the full load transmitted to the tensioned rods.

As further regards the structure of the arms **41** and **42**, it is preferred that these arms consist respectively of pairs of spaced arm members **72**, **73**, and **74**, **76**. Considering the arm **41**, the spaced bifurcated elements **44***a* and **44***b* may be formed as integral extensions respectively of the members **72** and **73**. The arm members are secured rigidly together by means of nuts **77**, bolts **78**, and spacers **79**. The bar **55** extends through the spaces between the arm members, and similarly, the link **43** is pivotally secured between the arm members.

It will be seen that the arms **41** and **42** as shown pivotally mounted at spaced positions on the link **43** have their center lines in relatively parallel relationship. Movement of the arms toward one another about pivot points **83** and **84** thus requires a minimum of pivotal movement of the jaws **23** and **24** relative to their respective arms, thereby minimizing the friction involved in moving the arms together. Inasmuch as the tendons **11** and **12** to be joined are not always spaced the same distance apart, it is desirable that the length of the link **43** be adjustable to provide the aforesaid generally parallel relationship of the arms. As here shown, link **43** is composed of a tubular center section **80** and a pair of removable end members **81** and **82** which are in turn pivotally connected to the adjacent ends of arms **41** and **42** by pivot bolts **83** and **84**. Since the force on the link member during operation of the device is in compression end members **81** and **82** are provided with flanges, as seen in FIG. 2, for abutting the opposite ends of the tubular center section **80**. Preferably, ring clamps **85** and **86** are mounted around the opposite ends of the tubular center section for squeezing down upon the inserted portions of end members **81** and **82** so as to hold the latter in place, the opposite ends of the tubular center section being slitted to permit compression by the ring clamps against the end members. Adjustment of the length of the link **43** may accordingly be conveniently effected by dismantling the center section **80** and end members **81** and **82** and replacing the center section with one of appropriate (longer or shorter) length.

An alternative construction of the apparatus is depicted in FIG. 8. The coupler **17***a*, as shown in FIG. 8, is again secured to the tendon **12***a*, and preferably comprises a double-ended coupler of the type shown in FIG. 5. Separate jack engaging means **19***a* and **21***a* are here provided as protuberances on the tendons **11***a* and **12***a*, independent of the shoulders of the coupler **17***a*. Preferably, the protuberances are formed as removable wedge grip nuts, similar to the nuts **58** and **61** aforementioned, to be described more fully. To connect the tendons **11***a* and **12***a*, the jacking means force the two tendons together and into engagement with the two ends of the coupler **17***a*, whereupon the wedges of the coupler grippingly engage the tendons and hold them against return

movement. As described with the embodiment in FIG. 2, when the force of the jacking means is released, the setting of the wedge cam planes causes the initial tension in the tendons to be decreased. However, again in this embodiment, it is possible to take up the slack caused by this setting by applying force again for a second time thereby placing the ends of the tendons intermediate the wedge nuts in a slack unstressed condition. By providing the two wedges of the coupler **17***a* with oppositely wound spiral threads, rotation of the coupler causes the ends of the tendons to be drawn together tightly. Then when the jacking force is released, the tendons will remain in substantially the desired tension condition.

A third alternative construction of the apparatus suitable for practicing the present invention is depicted in FIG. 9, where again the coupler **17***b* is provided on the end of the tendon **12***b* and the bar **16***b* is provided on the end of the tendon **11***b*. Unlike the embodiment of FIG. 8, however, the coupler **17***b* need not be of the double-ended type, although shown as such, and could for example be welded or otherwise secured to the tendon **12***b*. The jack engaging means **21***b* here is provided by an end shoulder of the coupler **17***b*, while a removable wedge nut **19***b* mounted on the bar **16** spaced from its end preferably serves as the other jack engaging means. In drawing the tendons toward one another, the bar **16***b* is moved axially into gripping engagement with the coupler **17***b*, thus holding the tendons under tension. While it is appreciated that this construction does not afford the feature of rotational slack take-up as previously described regarding the other two embodiments, it nevertheless will be seen that a fewer number of parts are here required to join the opposed tendons than in the other embodiments. Since in various instances rotational slack take-up is not necessary, the reduction of parts is of course advantageous. Wedge grip nuts **19***a*, **21***a*, **19***b*, **59** and **61** are all here shown of similar construction. One of these nuts, identified as **19***a*, is illustrated in detail in FIG. 10, 11 and 12. The nut is particularly constructed for mounting either permanently or temporarily upon a bar or rod and for this purpose is split longitudinally for removal from the rod in two half sections. Accordingly, the nut housing is formed of a pair of half-cylindrical housing sections **91** and **92**, and these fit around a pair of half-cylindrical wedge sections **96** and **97**, the latter cooperating to surround rod **12***a* in the same manner as wedge member **34**. The wedge sections **96** and **97** have internal bar engaging surfaces **98** formed with teeth for biting into and compressively engaging and gripping the periphery of the bar. Also similar to the coupling construction above described, the wedge and housing sections are formed with a plurality of longitudinally spaced annular inclined interfitting cam planes formed on the inner surfaces **93** and **94** of the housing sections and the external walls **99** of the wedge sections so as to translate pull of the bar in an axial direction relative to the nut into radially gripping forces of the wedge sections **96** and **97** on the bar. The housing sections **91** and **92** are here secured together by a pair of threaded bolts **101** and **102** which extend through bores **103** in section **91** into threaded engagement with tapped bores **104** in housing section **92**. It will be seen from the foregoing that the wedge nut can be readily mounted at any intermediate position on a bar member, thus enabling it for use with the fluid pressure means **49**, and the embodiments of FIGS. 8 and 9 as described hereinabove. An important feature of the nut is that it can be easily removed from the bar after it has been used. Consequently, the wedge nuts in the embodiments of FIGS. 8 and 9 can be taken off of the tendons after they have been connected, thus enabling their use elsewhere.

In FIG. 1, the present invention, as embodied in the above described methods is generally depicted in the operation of tensioning a plurality of rods **106** around a circular tank **107**. A bracket **108**, consisting of an eyelet, hook, ear or similar structure suitable for attaching a cable thereto, is provided on the arm **41** of the jacking means to enable the jack to be supported by a cable (not shown) from a suitable crane or the like disposed on top of the tank **107** and adapted to move along the tank's periphery. In mounting the rods **106** around the tank, a plurality of rods may be simply spliced together at adjacent ends by a coupler **28**, as shown in FIG. 5. This generally is best accomplished by first mounting the wedges separately on the rod ends, after which the housing is threaded onto the pairs of opposed wedges. These spliced rods are then disposed around the tank with the spaced opposed ends of two rods remaining to be joined. As shown, a pair of couplers **17** and **26** and a connecting bar **16** are used to join the remaining ends in the manner described hereinabove with regard to the embodiment of FIG. 2, thus placing each of the encircling rod assemblies under tension. A high pressure fluid compressor **109** is connected to the fluid pressure fittings **64** and **65** of the hydraulic actuator **49** by a pair of conduits **111** and **112**. The compressor **109** is preferably portable for movement around the tank together with the jacking means. The compressor illustrated is one manufactured by Lincoln Engineering Company of St. Louis, Mo., and ordinarily sold as a high pressure libricant pump. This unit is air-motor operated and may be produced to provide a 70 to 1 ratio so that 100 pounds per square inch air pressure will yield 7,000 pounds per square inch oil pressure for application to the hydraulic actuator **49**. Of course, any suitable commercially available high pressure hydraulic source may be used.

It will be appreciated that with a relatively large tank, the joining together of the couplers **17** and **26** may not provide the desired tension in the tendons around the whole tank, since nonuniformity of tension is likely to be caused by friction. Consequently, it may be desirable to draw each pair of opposed tendon ends together to tension them, rather than simply splice them as shown, in addition to applying tension to the last pair of ends to be connected. To do this, considering the embodiment of FIG. 8, for example, the wedge members of the coupler would be separately mounted on the tendon ends, apart from the coupler housing, but just far enough to hold them on during initial tensioning. Then the coupler housing is threaded onto the wedges in the manner described to form the splice. By mounting the split wedge nuts on each tendon end, as shown in FIG. 8, it is then possible to bring the jack to each splice joint and draw the tendons all the way into the wedges, thus taking up slack at each splice position. After all the splices are tightened in this manner, further removal of slack can be accomplished, as described above, with regard to the second application of force at each splice connection, and rotation of the coupler to draw up the tendon ends as tightly as possible. Each of the splice connections, of course, can similarly be made in accord with the embodiments of the invention depicted in FIGS. 2 and 9. In order to measure the tension in the bars to assure that the desired stressing conditions are achieved, it is preferable that a device such as a Howlett Extensometer be used in conjunction with each slack take-up point to observe the tensile forces as the jack is operated. Preferably, the housing of the present coupler is formed of high strength steel so as to carry the loads imposed upon it and the wedge members are preferably formed of hardened steel so as to take a proper bite into the rods.

From the foregoing, it is apparent that the present invention affords a highly convenient method for connecting and placing tendons under tension, and which can be utilized to utmost advantage in providing extremely high tensile forces that approach the maximum tensile strength of the tensioned members.

I claim:

1. The method for connecting and tensioning two elongated, end opposed tendons comprising the steps of:

(a) providing a pair of bar members respectively one on each of the opposed ends of said tendons in spaced aligned relation;

(b) disposing between said two bar members a double ended coupler having one end of said coupler comprised of a bore having a sleeve-like wedge therein, said bore and wedge having complementary left-hand threads for effecting longitudinal displacement of the wedge relative to the bore, and the other end of said coupler comprised of a similar bore and wedge having right-hand threads for effecting longitudinal displacement of the latter wedge, said wedges being formed for receiving said bar members and holding them against return movement;

(c) applying a force to said tendons to urge them toward one another and to move said bar members into operative connecting engagement with said wedges and said coupler;

(d) releasing said force from said tendons so as to place bar portions and tendons under tension;

(e) applying a force to said tendons a second time and urging them together until a predetermined tension is presented in said tendons, said latter step also serving to move said tendons longitudinally toward said coupler to remove the tension therefrom and place it in slack condition; and

(f) taking up the slack in said coupler by rotating said coupler about its axis in a direction causing said wedges of said coupler to pull the ends of said bar portions toward one another.

2. The method for connecting and tensioning two end opposed tendons comprising, selecting a pair of coupler members each having a bore with gripping elements threadedly secured therein for axially receiving a bar member and holding it against return movement, selecting a pair of such bar members, one said bore and corresponding elements having left-hand threads for effecting longitudinal displacement of the elements relative to the bore and the other said bore and elements having right-handed threads to effect longitudinal displacement of the latter elements, providing one said pair of members respectively on the opposed ends of said tendons, securing the other said pair of members together in oppositely outwardly facing relation to form a substantially unitary connecting member, disposing said connecting member intermediate said pair of members mounted on said tendons, applying force to said tendons to urge them towards one another and to move said pair of members on said tendon into operative connecting engagement with said pair of members on said connecting member, releasing said force, applying force to said tendons a second time and urging them together until a predetermined tension is present in said tendons, said latter step also serving to move said tendons longitudinally toward said connecting member to remove the tension therefrom and place it in a slack condition, and taking up said slack by rotating said connecting member about its axis in a direction causing said gripping elements to increase the tension in said connecting member.

3. The method of connecting and tensioning two elongated, end opposed tendons comprising:

(a) providing a pair of double ended couplers, each of said coupler ends being formed with a bore and wedge formed to radially grip a member urged into said coupler ends and formed to hold said member against return movement;

(b) mounting each of said couplers on said opposed tendon ends by urging one of said couplers onto one of said opposed tendon ends, and urging the remaining coupler onto the remaining tendon end;

(c) providing a connecting bar having a length sufficient to extend between said couplers as mounted on said tendon ends upon applying a tensioning force to said tendons;

(d) disposing said connecting bar between said couplers in alignment with said tendons;

(e) applying force to said tendons to urge them toward one another and to displace the ends of said couplers into operative engagement with said connecting bar; and

(f) releasing said force from said tendons so as to place said bar, couplers and tendons under tension.

4. The method of claim 3 wherein one said coupler comprises a housing having a sleeve-like wedge therein with said housing and wedge having complementary left-hand threads for effecting longitudinal displacement of said wedge relative to the housing and the other said coupler comprises a similar housing and wedge having right-hand threads for effecting longitudinal displacement of the latter wedge, and wherein is provided the further steps of applying force to said tendons a second time and urging them together until a predetermined tension is present in the two opposed tendons, said latter step also serving to move said tendons longitudinally toward said bar to remove the tension therefrom and place it in a slack condition, and taking up the slack in said bar by rotating said bar about its axis in a direction causing said wedges of each coupler to pull the ends of the bar away from one another.

5. The method of connecting and tensioning elongated, end opposed tendons as defined in claim 3, and the additional step comprising:

positioning said tendons in end opposed relation by encircling a cylindrical concrete tank with at least one elongated tendon in a manner to dispose two tendon ends in spaced confronting aligned relation.

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