June 17, 1969 G. H. HOWLETT 3,449,876

TENDON ANCHORAGE

Original Filed Feb. 24, 1965 Sheet 1 of 3

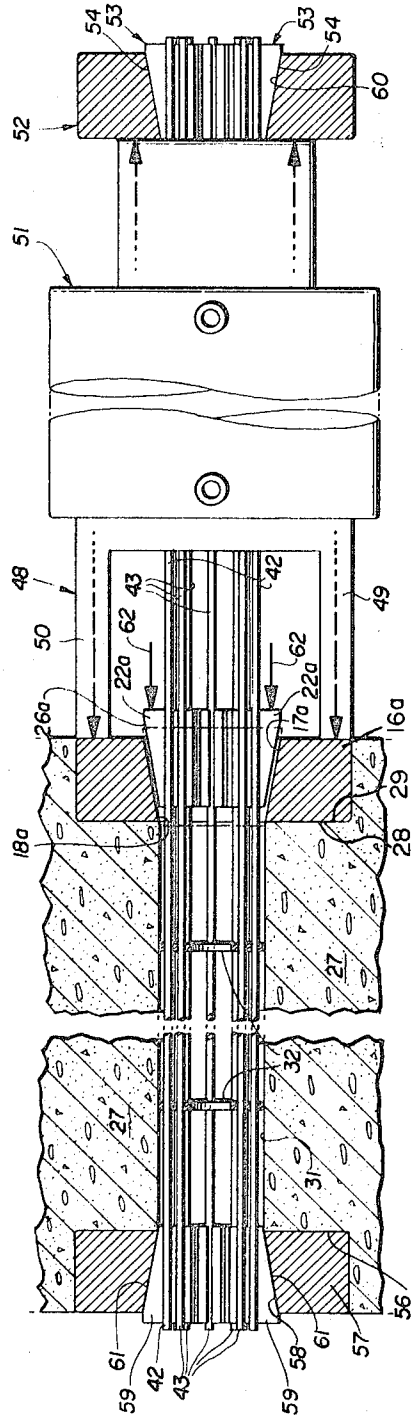


FIG. 1

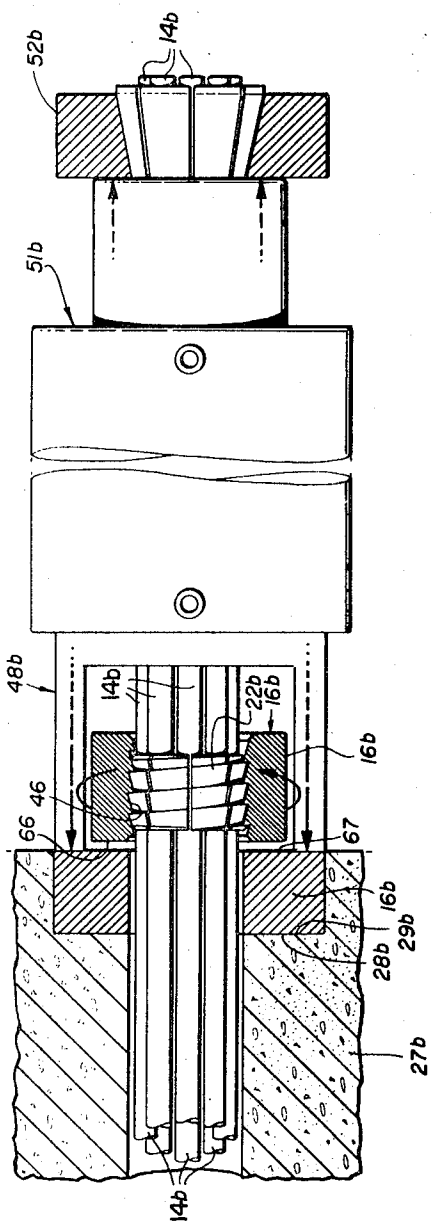


FIG. 5

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TENDON ANCHORAGE

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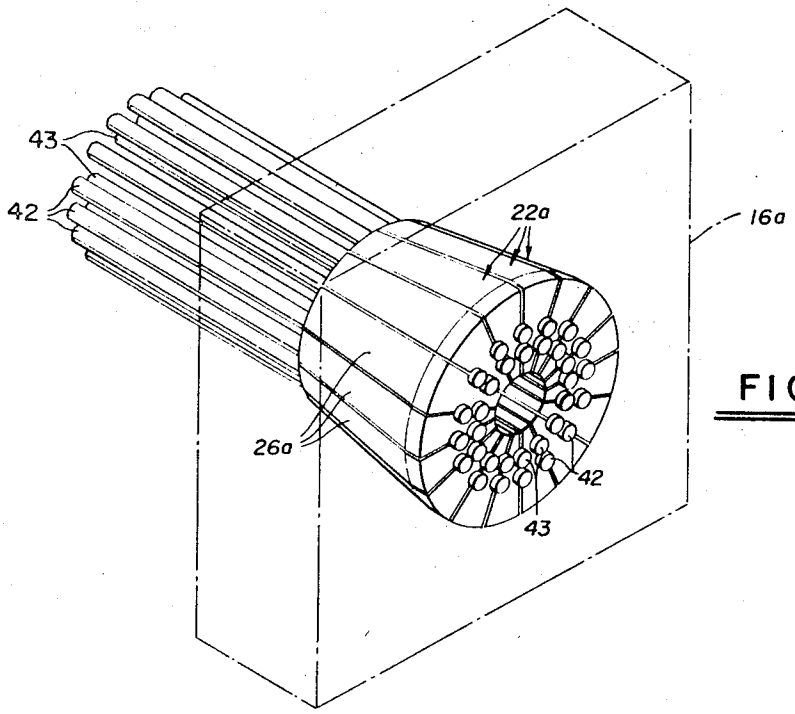


FIG. 2

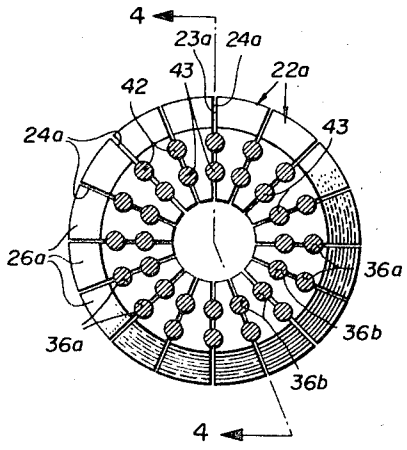
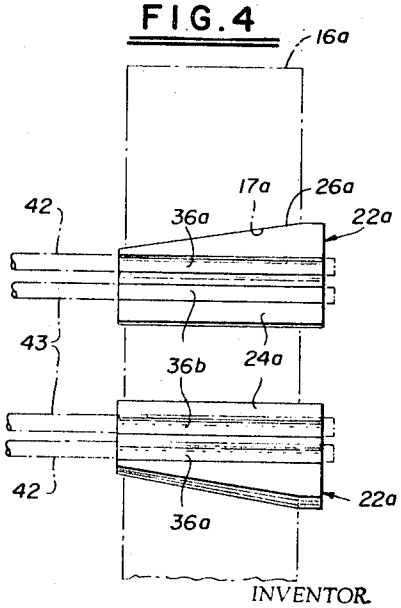


FIG. 3

FIG. 4



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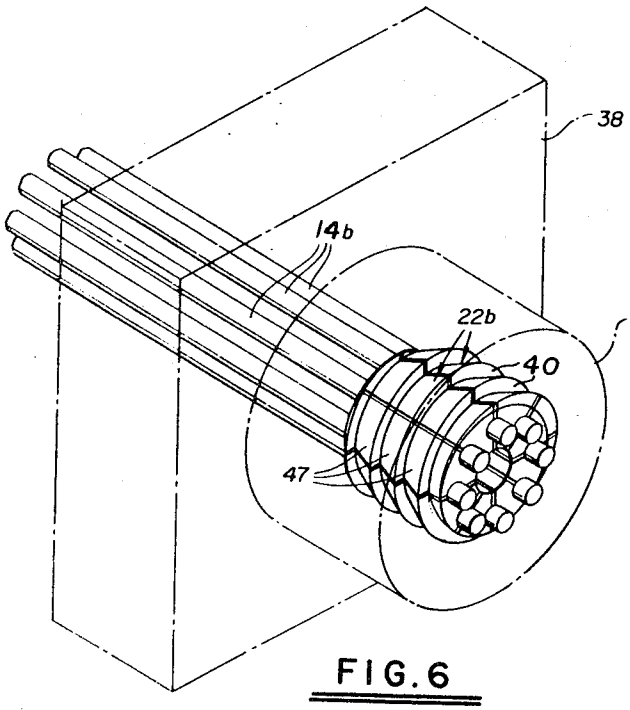


FIG. 6

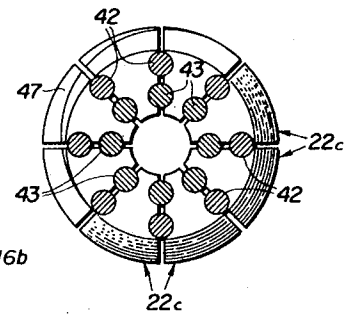


FIG. 9

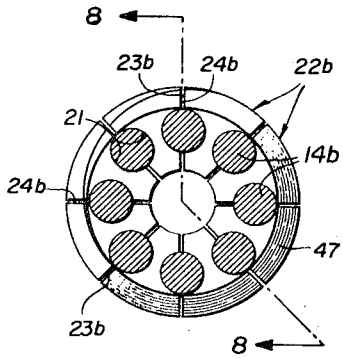


FIG. 7

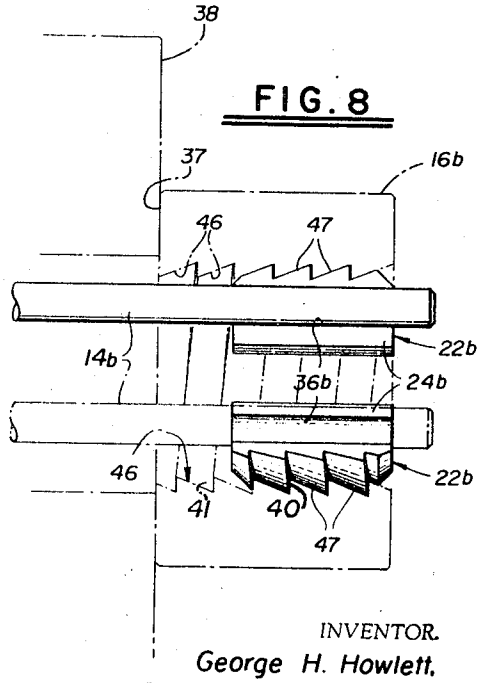


FIG. 8

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TENDON ANCHORAGE

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Continuation of application Ser. No. 434,978, Feb. 24, 1965. This application Feb. 21, 1968, Ser. No. 707,067
Int. Cl. E04c 5/01, 5/08; F16g 11/05
U.S. Cl. 52—230 7 Claims

ABSTRACT OF THE DISCLOSURE

A tendon anchorage for use in connection with pre-tensioning and post-tensioning concrete is disclosed which includes an anchor member formed with a bore with a plurality of wedges mounted therein and the wedges are designed to receive pairs of tendons between their adjacent side faces such that tensioning of the tendons causes said wedges to apply a clamping force which is self-adjusting between each pair of tendons whereby the tendons are secured in the anchorage with a substantially equal force which is proportional to the tension applied to the tendons. In addition, the anchorage may include interfitting convergent cam planes for inducing the clamping forces in the wedges.

This is a continuation application of application, Ser. No. 434,978, filed Feb. 24, 1965, now abandoned. The present invention relates to anchorage devices for tendons, bar, wire and cable, in structures wherein the anchorages are designed to hold near or up to the ultimate strength of the tendons.

Tendon anchorages fall into several general types depending upon the type of tendon used. For example, bar tendons may be anchored by threading the tendon or by the use of wedges. Wire tendons are not adapted for threading and wedges are most commonly used for anchoring wire tendons. In the case of cables, the wire ends may be splayed out and secured in a poured socket which may be filled with zinc or similar material forming a relatively large casting. Threading weakens the tendon because of reduction in cross sectional area and also because any notching of the tendon creates "stress raisers." In the case of wedges, it is highly desirable that the wedges be automatically self-setting so as to increase their clamping force on the tendon as the tensional forces on the tendon are increased and that each tendon be clamped or gripped with substantially the same gripping force. In order to obtain such a self actuation some anchorages have provided the jaw faces of the wedges with sharpened teeth or serrations which are capable of biting into the tendon. Such teeth or serrations like the threads are undesirable in creating "stress raisers" at the point of contact.

Another serious problem encountered with multiple wedge tendon anchorages of the prior art occurs when the load on the tendons rapidly changes from a high tension load to a compressive load. This load reversal phenomenon occurred, for example, in many prestressed structures during the Alaskan earthquake. Tendons, once under high tension loads, momentarily went slack causing the tendon gripping wedges to fly backwards out of the anchorages, and when the load reversed again, the anchorages failed completely.

Accordingly, it is an object of the present invention to provide a multiple tendon anchorage which will be self adjusting to positively clamp all of the tendons in the anchorage with equal force and provide for equal tensioning of the tendons and to accomplish the foregoing in a device of minimum size and composed of a minimum

number of durable parts capable of permanent trouble-free service.

A still further object of the present invention is to provide a tendon anchorage in which the tendons may be tensioned, tested and re-tensioned without destroying or replacing the anchorage or any of the parts thereof.

Another object of the present invention is to provide a multiple tendon anchorage which affords an easy and simultaneous tensioning of the tendons.

Still another object of the present invention is to provide a multiple tendon anchorage of compact design which is safer and more reliable when installed and easier to assemble in the field.

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 drawings and description may be adopted within the scope of the invention as set forth in the claims.

Referring to said drawings (three sheets):

FIGURE 1 is a cross sectional view of the tendon anchorage constructed in accordance with the present invention and shown in conjunction with a structural member.

FIGURE 2 is a perspective view of the anchorage shown in FIGURE 1.

FIGURE 3 is a cross sectional view of the anchorage shown in FIGURES 1 and 2.

FIGURE 4 is a cross sectional view of the anchorage shown in FIGURES 1, 2, and 3 and is taken substantially on the plane of line 4—4 of FIGURE 3.

FIGURE 5 is a cross sectional view similar to FIGURE 1 but showing a modified form of the anchorage of the present invention.

FIGURE 6 is a perspective view of a portion of the anchorage illustrated in FIGURE 5.

FIGURE 7 is a cross sectional view of the anchorage portion shown in FIGURE 6.

FIGURE 8 is a cross sectional view of the anchorage portion shown in FIGURES 6 and 7 and is taken substantially on the plane of line 8—8 of FIGURE 7.

FIGURE 9 is a cross sectional view of an anchorage portion constructed in accordance with FIGURES 7 and 8 and further formed with pairs of tendon gripping recesses.

The tendon anchorage of the present invention comprising an anchor member **16***a* having a wall defining a frusto-conical bore **17***a* dimensioned at the small diameter end **18***a* thereof to receive a plurality of tendons **42** and **43** to be tensioned, a plurality of wedges **22***a* mounted in the bore forming a frusto-conical assembly therein with the peripheral sides **26***a* of the wedges engaged with the bore wall and the side faces **24***a* of the wedges being mounted in spaced opposed relation for receiving and clamping tendons therebetween, the opposed side faces of adjacent wedges being formed with laterally spaced pairs of opposed longitudinally extending recesses **36***a* and **36***b* each formed and dimensioned to receive and engage partially around the periphery of one of the tendons, the peripheral sides of the wedges having substantially the same pitch as the bore wall for mated sliding engagement therewith whereby upon tensioning of the tendons wedges **22***a* are drawn in the direction of small diameter bore end and thus into clamping engagement with the tendons. The clamping force generated is proportional to the number of tendons secured by wedges **22***a* and the aforesaid pitch of the wedges and bore wall and the area of contact between the wedges and tendons. These parameters are selected to obtain a positive clamping of the

tendons up to their ultimate tensile strength without substantial damage to the tendons; and the anchor member **16***a* is dimensioned and constructed to supply the requisite banding force.

The anchorage is illustrated in FIGURE 1 is applied to the post-tensioning of a structural member **27**, such as a concrete beam, although, as will be understood, the anchorage device of the present invention may be used for positively securing and anchoring a plurality of tendons in substantially any structure including cable and bridge anchorages and the like. When applied to the post-tensioning of a concrete beam as illustrated in FIGURE 1, the anchorage member **16***a* is provided with a face **28**, adjacent the small diameter end **18***a* of bore **17**, for engaging an abutment **29** of the structural member; and the concrete member is sometimes formed with a tunnel **31** in which the plurality of tendons **42** and **43** may be placed and supported by longitudinally spaced separators **32**.

Anchor member **16***a* is preferably made of steel plate of sufficient thickness to withstand the bending loads imposed and also substantially corresponding in thickness to the length of the wedges **22***a*, which in turn determine the area of contact between the wedges and tendons. Some unsupported overhang of the wedges at the opposite sides of the anchor member is permissible. Because of the very high order of clamping forces developed by the present multiple wedge anchorage construction, the anchor member must have a diameter or circumferential mass surrounding the bore of sufficient radial dimension to contain and withstand the extremely high radial forces to which the member is subjected as a reaction to the very high order of clamping force. This strength to prevent bursting of the anchor member is sometimes referred to as banding strength or force.

The configuration of the wedges in contact with the tendons may be adapted to suit particular tendons and installations, it being sufficient that there be provided enough area of cotnact to provide automatic actuation of the wedges and positive anchoring of the tendons. For example, the opposite sides **23***a* and **24***a* of the wedges may be flat and yet provide in proper designs for adequate gripping of round bars or wires. Where flat sided tendons are used, flat sides on the wedges are preferred. The area of contact between the sides of the wedges and the tendons, in the case of circular tendons, may be substantially increased by forming at least one of the opposed radial side faces **23***a* and **24***a* of the wedges with a pair of longitudinally extending recesses or troughs **36***a* and **36***b*, which are each formed and dimensioned to receive and to engage patrially around the periphery of one of the tendons so as to increase the area of contact therewith. This effect may be maximized by forming opposed substantially semi-circular recesses in both of the opposed walls **23***a* and **24***a* as shown in FIGURE 3 so that the wedges fit around opposite sides of the tendons. A similar effect can be obtained by making the wedges out of somewhat softer material than the tendons so that the wedges will be caused to cold flow into greater contact with the tendons as the high order of magnitude of clamping force is exerted. Another alternate method of increasing the area of contact between the tendons and the wedges is to make the wedges out of a somewhat harder material than the tendons so as to produce a cold flow of the tendons into conformity with the shape of the wedges under the influence of the high order of magnitude of clamping forces used. In any such designs, the diameters of the tendons and the depths of the recesses or troughs or the amount of cold flow of the wedges or tendons are predetermined so that all of the circumferential spaces between the adjacent wedges is not taken up during the clamping action, but on the contrary some space is left between adjacent wedge faces **23***a* and **24***a* when the tendons are anchored.

Because of the automatic self adjusting characteristic of the wedges and the cold flow conformity of the wedges and tendons, manufacturing tolerances in the production of the parts of the present anchorage are easy to maintain. Also because of the foregoing characteristics, it is quite feasible to anchor different types of tendons, for example, stranded cable and bars in the same anchorage, intermixing the different types of tendons in the circumferential assemblage.

As herein above noted, the clamping force on the tendons secured in the anchorage. The number of tendons is the number of tendons and the total tensioning force exerted by them. Consequently increased clamping force may be obtained by increasing the total number of tendons secured in the anchorage. The number of tendons is conveniently increased in the present apparatus by mounting a plurality of tendons **42** and **43**, as shown in FIGURES 1 to 4, between the opposed faces **23***a* and **24***a* of each adjacent pair of wedges **22***a*. As here shown, the two sets of such troughs **36***a* and **36***b* are disposed in concentric circles in relation to the axis of the bore of the anchor member. As will be understood, any number or tendons may be mounted between the opposed faces **23***a* and **24***a* of the adjacent wedges and the automatic self-adjusting action of the wedges will ensure equal clamping of all of them.

Another embodiment of the present invention is shown in FIGURES 5 to 9 wherein the anchorage is designed to permit taking up or the tensioning of the tendons, testing of the strain on the tendons after a given period of time, and retention of the wedges within the anchor member upon reversals in the tendon loading. In this embodiment, the anchor member **16***b* and the plurality of wedges **22***b* are formed with a pluarlity of longitudinally spaced annular interfitting cam planes **46** and **47** on the interior wall of the bore of the anchor member and on the exterior of the wedges. As will be observed from the drawings, these cam planes diverge away from the direction of force exerted by the tendons so as to translate the sum total of axial forces of the tendons into transverse clamping forces exerted by the side faces **23***b* and **24***b* against the tendons **14***b* positioned therebetween. As a further important feature of this form of the invention, the cam planes **46** and **47** are spirally formed to provide joint threading of the wedge members **22***b* into and out of the bore of the anchorage nut member **16***b*. The plurality of threaded cam planes provides a more compact structure where this is desirable and also permits easy relative rotation of the exterior nut member **16***b* for taking up of play or free space where such action is desirable. Axially extending troughs or recesses **36***b* may be formed in either one or both of the side faces **23***b* and **24***b*, as in the above embodiment, for the securing of one or more tendons between each opposed pair of faces **23***b* and **24***b*.

It is also an important feature of this form of the in vention that cam planes **46** and **47** are interconnected by at least one surface **40** and mating surface **41**, formed in the wedges and bore wall respectively, so as to limit axial displacement of wedges **22***b* in the direction of divergence of the bore. Spirally formed cams achieve this end and in addition a series of longitudinally spaced diverging cam surfaces which are circular, not a continuous spiral cam surface, would also suffice. Such a series of circular cams (not shown in the drawing) can be formed exactly as shown in FIGURES 5 to 9 with the exception that the cam lands would not be interconnected. An anchorage having circular or spiral cam planes formed in the peripheral sides has the substantial advantage of being formed in a manner to be positively retained by anchor member **16***b* against being urged out of the anchorage in the direction of divergence of the cam planes. This is an important safety feature of the anchorage of the present invention for applications where a stress reversal or reversal of loading is possible. Spiral or circular cam planes, constructed as illustrated and described

herein, will not be thrown out of the anchor member if tendon loading is momentarily released, although the clamping action of wedges **22***b* will tend to be released. When the tendons again are loaded, wedges **22***b* will re-clamp the tendons, and although as re-clamped the anchorage will not grip the tendons at the axial load prior the load reversal, the tendons will not pull free and cause the entire structural member fail. Thus, the structural member must be replaced or retensioned, but it maintains the load long enough after the reversal to allow evacuation of property or personnel endangered by the weakened structure.

Both spiral and circular cam constructions have the additional assembly advantage of allowing the tendons to be inserted into recesses **36***b* under the field assembly conditions normally encountered without forcing the wedges backwards and out of member **16***b*. Moreover, circular cam planes also afford a simultaneous take-up during tensioning by sliding the wedges together axially along the tendons.

When circular cam planes are formed on the wedge peripheral surfaces, the wedge assembly obviously cannot be rotated into the anchor member to be assembled. Instead wedges must be individually inserted into member **16***b* and urged up into the mating recesses in the anchor member and rotated or clustered together to allow later wedges to be inserted. The depth of the recesses and the spaces between the adjacent wedges must be selected to allow the wedges to be urged into abutting relationship and the last wedge to be inserted.

In FIGURE 9, a wedge assembly having wedges **22***c* formed to receive and clamp pairs of tendons **42** and **43** is illustrated. The periphery of wedges **22***c* are formed with spiral cam lands **47** suitable for use with a nut member **16***b* in a manner as shown and described in connection with FIGURES 5 to 8. Thus, the advantages of gripping pairs of tendons and diverging cam plane can be enjoyed.

Various hydraulic jacking units are available for applying tension to the tendons. A typical layout is illustrated in FIGURE 1 in which a hydraulic jack **51** is mounted between a jacking head **52** and a jack chair **48**. The hydraulic jack **51** is formed with a central open core for surrounding the tendons **42** and **43** and to bear against the jacking head **52** concentrically of the tendons. Similarly jack chair **48** is provided with spaced legs **49** and **50** which bear upon the anchor member **16***a* on opposite sides of the conical assembly of wedges **22***a*. Jacking head **52** is here formed as a typical anchorage of the type herein above described having a plurality of frusto-conical wedges **53** mounted on opposite sides of each of the tendons and with their tapered outersides **54** in sliding engagement with an internal frusto-conical wall **60**. As will be observed the small diameter end of the wedge assembly is adjacent the hydraulic jack so that the wedges will move automatically into clamping engagement with the tendons as the hydraulic jack applies axial force to the jacking head as indicated by the arrows in FIGURE 1.

The integrated beam structure illustrated in FIGURE 1 includes another anchorage at the left hand side of the figure for securing the tendons **42** and **43** at that side of the beam. This anchorage is again similar in all respects to anchorages herein above described and includes an anchor member **57** which is mounted against an abutment **56** of the beam and which is formed with a frusto-conical bore as defined by internal wall **61** for receiving therethrough the plurality of tendons **42** and **43**; and a plurality of segmental frusto-conical wedges **59** which are mounted between the tendons and have their exterior tapered surfaces **58** in mated sliding engagement on wall **61**. As will be observed from FIGURE 1, the small diameter end of the wedge assembly faces in the direction of the tensioning of the tendons so that the latter will be automatically anchored by wedges **59** as tension is applied by the hydraulic jack. As will be further observed from FIGURE 1, tensioning of the tendons by the hydraulic jack will be accompanied by a displacement of the tendons at anchor member **16***a* in a direction loosening wedges **22***a*. When the tendons are brought up to desired tension, wedges **22***a* are reset to the left, as seen in the view and as indicated by arrows **62**, so that upon releasing of the force applied to the jacking head, wedges **22***a* will move automatically to anchor the tendons in tensioned position.

The use of a nut anchorage construction as illustrated in FIGURE 5 makes possible the tensioning and re-tensioning of the tendons so as to take up for tensioning loss which accompanies the slight movement of the wedges to their setting position. In this arrangement, the left hand end of tendons **19***b* are anchored in the manner illustrated in FIGURE 1. As hydraulic jack **51***b* applies its expansion force to jacking head **52***b* and chair **43***b*, nut member **16***b* will be carried to the right, as seen in the figure in slightly spaced relation to anchor member **16***b*, which is mounted with its face **28***b* against abutment **29***b* provided by beam **27***b*. When the tendons are fully tensioned, nut body **16***b* may be rotated so as to move axially to bear with its end face **66** against the adjacent end face **67** of the anchor member **16***b* to thereby initially set wedges **22***b* for automatic anchoring of the tendons in place when the jacking tension is released.

At any time thereafter the tensioning of the tendons may be tested without destroying or replacing the anchorage by simply reinstalling hydraulic jack **51***b*, jacking head **52** and chair **48***b*; tensioning the tendons while observing a pressure gauge on the hydraulic jack; and testing the anchor body **16***b* until it may be rotated. Reading the pressure gauge on the hydraulic jack at the moment the anchor body **16***b* is initially rotated indicates the magnitude of the preset tension on the tendons. After the tendons have been re-tensioned, the nut body **16***b* may be run down against face **67** to positively anchor the tendons in their newly tensioned condition upon release of the jacking force.

The present anchorage is capable of producing clamping forces exceeding the ultimate strength of the steel used in the tendons and wedges. By the addition of tendons to the assembly thereby increasing the total aggregate pull on the wedge assembly, this gripping or clamping force can be increased to the point of squeezing or extruding either the tendons or the wedges whichever will flow first. A similar effect may be obtained by decreasing the angle of taper or pitch of the frusto-conical wall and wedges. On the other hand, the likelihood of deforming the tendons or wedges may be counteracted by increasing the area of contact between the wedges and tendons as for example the provision of the longitudinal troughs or recesses **36** or the increasing of the length of the tendon. The three principal factors in the design of the anchorage are therefore the number of tendons which are to be anchored; the pitch of the wedges and bore wall; and the area of contact between the wedges and the tendons, it being understood that in all cases the design should provide free sliding engagement between the wedges and bore wall with minimum friction therebetween, and adequate, and in some instances maximum, frictional engagement between the wedges and tendons. These factors are adjusted and proportioned to fit individual tendon anchorage arrangements so as to obtain positive clamping of the tendons up to their ultimate strength without substantial damage to the tendons.

By way of example, a satisfactory design in the case of thirty-two tendon assembly illustrated in FIGURES 1 to 4 using ¼-inch wire tendons having an individual tensile strength of 10,000 to 11,000 pounds providing an aggregate tensile force of 320,000 to 352,000 pounds may have the following parameters:

Wedge pitches in the range of 10° to 15°. Wedge length in the range of 2" to 2½". Anchor member a 10" x 10"

plate, 2" thick composed of C–1040 steel. Space between wedge faces at gripping strength 1/16 to 3/16 inch.

The aforementioned dimensions are given to purposes of illustration and designers may change these to suit individual installations. For example, the pitch of the wedges and bores may vary widely depending upon the number of tendons used from about 5° to 20° or more. In the case of large cables, as used for example in a cable suspension bridge, the ends of the large main cable may be splayed out at the anchorages into cluster groupings with each cluster resembling one of the embodiments of the present invention, as for example the multi-wire embodiment of FIGURES 1 to 4. There are conditions calling for a dead end anchorage wherein it may be desirable to flare the wires out as in the present Freyssinet anchorage. In such case, the individual wire troughs will be placed on an angle to the axis, out of parallel, and the wires may be grouped closer together at the point where they go into a beam or the like where for example they may touch one another. When an anchorage is employed which incorporates inclined cam planes, as illustrated in FIGURES 5 to 9, the cam planes may be formed with a pitch as high as 30°, with 22° being preferable on an eight tendon anchorage having wedges from 2 to 3 inches in length. As above set forth, the pitch is related to the number of tendons anchored and the area of the wedge which engages the tendon.

I claim:

1. A tendon anchorage comprising an anchor member having a wall defining a frusto-conical bore dimensioned at the small diameter end thereof to receive a plurality of tendons to be tensioned, a plurality of wedges mounted in said bore forming a frusto-conical assembly therein with the peripheral sides of each of said wedges engaged with said bore wall and the side faces of each of said wedges being mounted in spaced opposed relation for receiving and clamping tendons therebetween, said opposed side faces of adjacent wedges being formed with laterally spaced pairs of opposed longitudinally extending recesses, each formed and dimensioned to receive and engage partially around the periphery of one of said tendons, said peripheral sides of said wedges having substantially the same pitch as said bore wall for mated sliding engagement therewith whereby upon tensioning of said tendons said wedges are drawn in the direction of said small diameter bore end and thus into clamping engagement with said tendons with a clamping force proportional to the number of tendons secured by said wedges and the aforesaid pitch of said wedges and bore wall and the area of contact between said wedges and tendons.

2. A tendon anchorage as defined in claim **1**, wherein said side faces are formed to extend radially from said peripheral sides toward the longitudinal axis of said bore.

3. A tendon anchorage comprising, an anchor member having a bore dimensioned to receive therethrough a plurality of tendons to be tensioned, a plurality of wedges mounted in said bore and formed to receive a plurality of tendons with each of the tendons disposed between opposed side faces of pairs of adjacent wedges disposed for clamping against the opposite sides of the tendons, the peripheral sides of said wedges and the wall of said bore being formed with a plurality of longitudinally spaced annular interfitting cam planes diverging away from the direction of force exerted by said tendons and inclined to the axis of said bore so as to translate the sum total of axial forces of said tendons into transverse clamping forces exerted by said side faces against said tendons.

4. A tendon anchorage as defined in claim **3**, wherein said cam planes are spirally formed to provide joint threading of said wedges axially of said bore to afford, upon relative rotary displacement of said member, a simultaneous and equal take-up of said tendons and wedges.

5. A tendon anchorage as defined in claim **3**, wherein at least one pair of said opposed pairs of side faces of said wedges is formed with two longitudinally extending recesses formed and dimensioned to receive and to engage partially around the periphery of one of said tendons to increase the area of contact therewith.

6. A tendon anchorage as defined in claim **3**, wherein said side faces are formed to extend radially from said peripheral sides toward the longitudinal axis of said bore.

7. A tendon anchorage as defined in claim **3** wherein said interfitting cam planes are connected by at least one pair of interfitting surfaces formed in the wall defining said bore and said peripheral sides to extend into said bore and limit axial displacement of said wedges in the direction of divergence of said cam planes formed in said bore.

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U.S. Cl. X.R

24—122.6, 126, 263.5