April 8, 1969 R. E. HUNTER 3,437,359

POST TENSIONING CONCRETE ANCHOR ASSEMBLY

Filed April 3, 1968

FIG. 1.

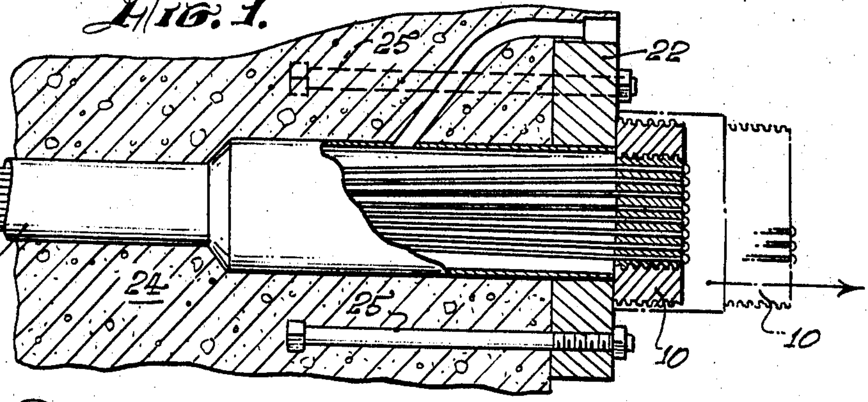


FIG. 3.

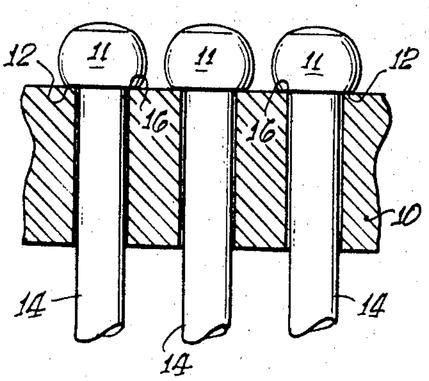


FIG. 2.

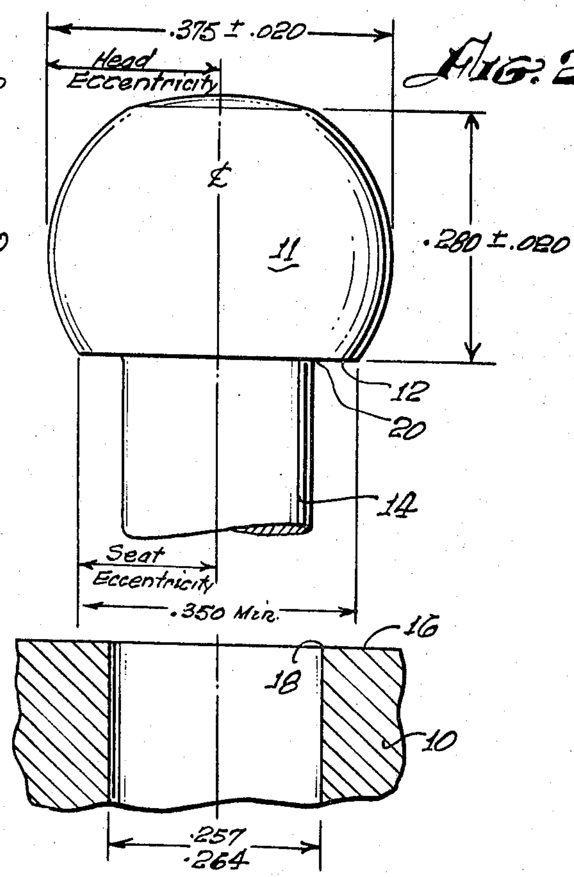
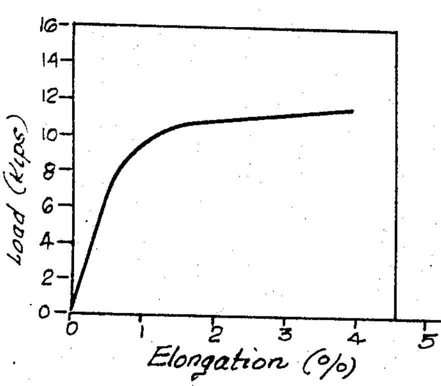


FIG. 4.



INVENTOR.
RAYMOND E. HUNTER,
By His Attorneys
Spensley & Horn.

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3,437,359
POST TENSIONING CONCRETE ANCHOR ASSEMBLY

Raymond E. Hunter, Lomita, Calif., assignor to Western Concrete Structures Co., Inc., Gardena, Calif., a corporation of California

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U.S. Cl. 287—20.3 3 Claims

ABSTRACT OF THE DISCLOSURE

The apparatus of the present invention in its presently preferred form includes a prestressing tendon having a head formed thereon, which tendon is stressed into bearing contact with an anchor seat. The head at the end of the tendon has a planar concentric bearing seat area in bearing contact with a planar bearing surface on the anchor member. A predetermined radius of curvature is provided between the planar bearing area of the head and the wire tendon upon which the head is formed.

This invention relates to prestressed concrete and more particularly to an improved tendon and anchor system for post tensioning concrete members.

Background of the invention

Prestressed concrete has become increasingly well known in the construction art and relates to concrete structures in which there have been introduced internal stresses of such magnitude and distribution that the stresses resulting from given external loadings are counteracted to a desired degree. One method of prestressing concrete members is the post-tensioning method by which steel tendons are positioned in a relaxed condition within the concrete members. After the concrete is hardened the steel tendons are placed under tension to exert compressive forces upon the concrete. Typically, such tendons are comprised of a plurality of steel wires .025 inch in diameter with upset cold formed heads on the end of each wire which upset head is in bearing contact with an anchor member to transmit the force to the anchor member and thus to the concrete being stressed.

The present invention is particularly adapted to be used in connection with prestressed post-tensioned concrete and will be described in detail in connection with such construction. However, other uses of the apparatus of the present invention and its use in connection with other materials will be apparent to those skilled in the art. As defined above, prestressed concrete contemplates the introduction of internal stresses in the concrete members to offset external loading stresses to a required degree. As an example, by one method of post-tensioning a concrete slab, a plurality of tendons are suspended within the form used for pouring the slab and are encased such that they can be stretched within the concrete after the concrete is hardened. The tendons are extended through bearing plates which are positioned against opposite edges of the slab. After the concrete has been poured and allowed to set the tendons are stretched to the desired tension by means such as hydraulic jacks which engage the tendons and pull them outward from the edge of the slab. The elongated tensioned tendons are then anchored against the bearing plates thereby exerting a compressive force at the edges of the slab.

Those portions of the prestressing apparatus with which the present invention deals, are particularly, the head formed upon the wire from which the post-tensioning tendon is formed and the portion of the anchor member which is in bearing contact with the wire heads of the

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tendon. As discussed hereinbefore in a typical example of post-tensioning apparatus the tendon extends through a bearing plate or comparable member which is in contact with the edge or surface of the concrete. Adjacent the bearing plate is an anchor member which is typically a steel member having a plurality of openings therethrough equal in number to the number of wires forming the tendon. Each of the wires then extends through the anchor member and at the end of each wire there is formed a wire head which has a cross-sectional configuration greater than the diameter of the opening through the anchor member. Any force directed inwardly by the tendon upon the anchor member is then transmitted by the anchor member to the bearing plate and thus to the concrete member. In an illustrative embodiment the anchor member takes the form of an anchor washer which is a cylindrical steel member having the plurality of openings equally spaced and longitudinally extended through the cylinder. The cylindrical surface is male threaded to allow the connection thereto of a hydraulic ram or jack which exerts the tensioning force on the tendon by pulling the anchor washer away from the concrete surface and bearing plate.

As the washer is pulled from the bearing plate the tendons are stretched and are retained in the anchor washer by reason of the heads on each of the wires being greater in cross sectional configuration than the diameter of the holes through which they extend. At the predetermined desired elongation and tension the bearing plates are subjected to the compression force of the tendon by inserting shims or other suitable force transmitting members between the washer and the bearing plate to retain the bearing plate in the spaced away position to which it was removed. The tension force of the tendon is thus transferred from the plurality of wires to compression in the concrete through the bearing plate. The load path first crosses the head anchor interface and finally crosses the bearing plate concrete interface. Between these points the load is carried by stressing washers, ring nuts, shims, or other special hardware designed and fabricated by the tendon manufacturer.

A cold formed or upset wire head has been in continuous use in the art since at least 1953 and is the standard method used by the post-tensioned prestressed art to attach the individual wires of a tendon to some member of the anchor assembly such as the anchor washer described above. Although some early wire heads took the form of a nail head, the wire head commonly used in the present state of the art is a round head of tulip form. An example of such a wire head is shown in U.S. Letters Patent No. 2,728,978. The cold formed wire head has a diameter substantially greater than the diameter through the anchor member with which it is in bearing contact. The head is so shaped that it engages the anchor seat of the member along a head surface which is at an angle of approximately 45° to the longitudinal axis of the head. A mating chamfer angle is formed in the anchor seat such that the interface between the wire head and the seat is at a bearing angle of approximately 45° from the longitudinal axis toward the transverse plane through the wire head. It can be seen that when tension is applied to the tendon wire the resultant forces between the anchor seat and the wire head are directed inwardly into the wire head.

Wire heads in the shape known to the prior art have an efficiency with respect to the wire of approximately 95% as measured by the present performance criteria for an assembled tendon.

In the present state of the art, however, the wire head efficiency is subject to many variations because of the number of variable which can be introduced in the manufacture of the wire head and the anchor seat. That is, any one of many parameters including the interface angle, the head diameter, the head height, the hole size and head eccentricity can effect the efficiency of the tendon system.

Additionally, even though such heads are said to be 95% efficient the fact that such efficiency is less than one hundred percent (100%) often leads to many questions in that if a failure occurs in the head rather than in the wire under ultimate load testing no reason is readily assignable for the failure. Any one of the variables mentioned above can effect the efficiency. Additionally, such efficiency criteria make no provision for the elongation of the wire and are not related to the actual ultimate strength of the wire.

It is an object of the present invention to provide a tendon and anchor assembly which is one hundred percent (100%) efficient.

It is another object of the present invention to provide a tendon and anchor assembly which includes a minimum number of variables which can be easily ascertained and controlled with a performance less effected by manufacturing variables.

It is another object of the present invention to provide an anchor and tendon assembly which is one hundred percent (100%) efficient for both ultimate strength of the wire and elongation of the wire.

It is a further object of the present invention to provide a wire head and anchor assembly in which quality control procedures can be readily provided to insure wire head and seat efficiencies of one hundred percent (100%) with respect to both the ultimate strength and the elongation of the wire, where such efficiency is based upon the actual ultimate strengh of the wire and not a minimum guaranteed ultimate strength.

Brief description of the drawing

In the drawing:

FIGURE 1 is a view partly in section showing a headed wire extended through an anchor member;

FIGURE 2 is an enlarged view of a tendon head and the bearing surface area of the anchor member;

FIGURE 3 is a sectional view of one assembly in which such tendons are utilized for purposes of illustration; and,

FIGURE 4 is a stress-strain curve for the tendon wire.

Description of the preferred embodiments

Referring now to the drawings and particularly to FIGURES 1 and 2, in accordance with the present invention a tendon and anchor assembly is provided by forming a wire head on each wire of the tendon in a particular configuration and with a specific controlled relationship with the anchor seat such that the entire force of the wire head against the seat is in the direction parallel to the longitudinal axis of the wire.

In FIGURE 1 there is shown a typical prestressing tendon assembly of the type in which the present invention is utilized. The tendon is formed of a plurality of wires **14** extended through an anchor member **10** with a head **11** as described hereinafter formed on the end of each wire. The wire head **11** has a head seat **12** in contact with the anchor bearing surface **16** of the anchor member **10**. The tendon extends through the concrete slab **24** being post-tensioned within a conduit **21** and through the bearing plate **22** which is in bearing engagement with the concrete slab **24**. The bearing plate is typically affixed to the slab by retaining bolts **25**. The anchor member **10** is shown in phantom in the stressed condition at which it would then be shimmed to thus pass the tension force in the tendon wires through the anchor member, shims, and bearing plate to the concrete slab.

Thus, referring to FIGURES 1 and 2, a tendon head **11** in accordance with the present invention has a bearing surface or head seat **12** which is planar and which is transverse to the longitudinal axis of the tendon wire **14**. The anchor bearing surface **16** is likewise planar and transverse to the longitudinal axis of the wire in the assembled condition. Since the relationship between the planar bearing surface areas and the materials of the anchor seat and wire head are critical, dimensions have been applied to FIGURE 2. Although not limited thereto the dimensioning of the wire head of the present invention is related to a wire which is .250 inch in diameter. The wire used in the United States today is normally .8 carbon, .7 manganese, .2 silicon analysis, hot rolled, cold drawn steel. Manufacture and acceptance of prestressing wire for button heading in the United States is governed by ASTM designation: 421–625 for Type BA, with the .250 diameter accounting for all of the wire used. In Europe it is the practice to vary the size of wire from 6 millimeters to 12 millimeters as well as the number of wires to obtain the desired tendon capacity. Accordingly, the wire head anchor assembly in accordance with the present invention is described throughout in connection with .250 diameter wire and from such description it will be apparent to one skilled in the art that the relationship of the dimensions and critical factors of the present invention can be applied to wires of different diameter.

It has been determined that in accordance with the present invention the area of contact between the wire head and the anchor must be sufficient to limit the bearing stresses to less than 2.0 times the ultimate tensile strength of the anchor or seat material. Thus, the area of the head seat **12** and the anchor seat **16** are inter-related and are determined by the wire and anchor material and sizes. Although the critical consideration of the present invention is the square planar head seat interface, manufacturing considerations make it desirable that some break in the corner **18** of the anchor seat be allowable. It has been found that small chamfers such as those resulting from deburring, have no adverse effect on the efficiency of the head seat. Similarly it has been found that some stress mitigation is required at the transition from the wire to the head in order to achieve one hundred percent (100%) efficiency of the tendon anchor assembly of the present invention. A radius fillet of .015 inch at **20** where the transition from wire to head occurs has been found to be acceptable since the materials used require relatively small fillet for the purpose. It can be seen that the fillet can be larger, the criteria being that the relationship between the surfaces **12** and **16** is such that the fillet is not in bearing engagement with the corner **18** of the anchor seat.

As discussed above the head anchor interface is so sized as to prevent bearing stresses in excess of 2.0 F_{tu} (where F_{tu} is the ultimate tensile strength of the bearing material). Greater bearing stresses will result in plastic deformation of the anchor. The material displaced in the anchor by hold collapse moves into the hole and if the bearing stresses are sufficiently high, places the critical wire head transition in radial compression.

Thus, in accordance with this present invention, hole collapse, which is the result of excessive plastic deformation at the anchor side of the head seat interface is controlled by limiting the bearing stresses to twice the ultimate strength of the anchor. It has been found that variables arising from production tolerances, however, require to assure one hundred percent (100%) efficiency of the system, that the design bearing stresses be of the order of no more than 1.5 times the ultimate of the anchor material.

Accordingly, in determining the relationship between the head seat and anchor seat interface it is necessary to first determine the anchor seat area required for the given materials being utilized. Thus, for a typical anchorage material of 4142 steel at R_C40 the minimum seat area (designated as A_s) is equal to

$$\frac{PW'}{2.0\ F_{tu}\ \text{min.}}$$

where PW' is the minimum guaranteed ultimate load of the wire and F_{tu} min. is the ultimate tensile strength of the anchorage material. For the anchorage material previously described and the wire described as the most typical in present use PW'=11.78 and F_{tu} is equal to 180K s.i. Therefore the minimum anchor seat area allowable is

$$\frac{11.78}{2.0\times180\times10^3}=.0327\ \text{sq. in.}$$

With the anchor seat area known, the seat diameter for the wire head can then be sized. It is necessary to assume the largest diameter hole permitted by the manufacturing tolerance.

Accordingly, in FIGURE 2 the head seat diameter is determined as follows:

$$D_s^2-.264^2\times/4=A_s\ \text{min.}=.0327$$

It can be seen that in accordance with the present invention the head diameter and head height are not variables which affect the efficiency of the tendon anchor assembly. The dimensions shown in FIGURE 2 are typical and satisfactory for the head seat and anchor seat interface areas shown in the typical embodiment.

By utilizing the above described relationships of wire head seat and anchor seat interface in a tendon anchor assembly an efficiency of the anchor assembly of one hundred percent (100%) is obtained. By one hundred percent (100%) it is meant herein in generalized terms that the tendon-anchorage system will develop the total strain energy of the wire itself, i.e., that formation of the head and anchor does not lessen the strain energy characteristics of the wire. Thus, referring to FIGURE 4 a load-elongation graph for a typical tendon wire having minimum ASTM·A·421 properties is shown. Tests conducted on the anchor-tendon assembly in accordance with the present invention have shown that failure of the tendon occurs beyond the minimum load and minimum elongation characteristics of the wire. It can be seen from the foregoing that wire failure away from the head would be achieved by the use of very hard (R_c60) anchor seat material. Such material is, however, too brittle for use and is metallurgically unsound where high confidence in the integrity of the anchor is essential. Also the use of such materials is not economically feasible. The present invention provides the means for achieving tendon anchor efficiency utilizing the optimum materials both with respect to mechanical properties and economics of the system.

I claim:

1. Apparatus for post-tensioning concrete in which a steel wire is tensioned and put in bearing contact with an anchor member which is in turn in bearing contact with

a surface of the concrete, the improvement comprising:
- a cold formed head on said wire, said head defining a head seat;
- an anchor member having an anchor seat;
- said wire extended through an opening in said anchor member;
- said head seat and said anchor seat being in planar bearing contact in a plane transverse to the longitudinal axis of said wire, said head seat and anchor seat having said transverse planar bearing interface over a predetermined area such that the bearing stresses at such interface are limited to a maximum of the order of 1.5 times the ultimate strength of said wire under said tension.

2. An anchor-tendon assembly for post-tensioning concrete in which a steel wire is tensioned and retained in bearing contact with an anchor member which is in turn in bearing contact with a surface of the concrete comprising:
- an anchor member, a longitudinal opening through said anchor member, an anchor bearing surface surrounding said opening, said anchor bearing surface being planar and transverse to said opening;
- a tendon wire extended through said opening;
- a cold formed head on said wire of substantially greater diameter than said opening, said wire head defining a head seat adapted to be placed in bearing contact with said anchor bearing surface, said head seat being planar and transverse to the longitudinal centerline of the wire, said head seat and anchor seat when in bearing contact being in planar bearing contact in a plane transverse to the longitudinal axis of said wire, said head seat and anchor seat having said transverse planar bearing interface over a predetermined area such that the bearing stresses at such interface are limited to a maximum of the order of 1.5 times the ultimate strength of said wire under said tension.

3. The apparatus as defined in claim 2 wherein the tendon anchor assembly has an efficiency of the order of one hundred percent (100%).

References Cited

UNITED STATES PATENTS

2,988,794	6/1961	Gutt	52—223 X
3,029,490	4/1962	Middendorf	52—223 X
3,225,499	12/1965	Kourkene	52—230

FOREIGN PATENTS

1,012,663	4/1952	France.

CARL W. TOMLIN, *Primary Examiner.*

WAYNE L. SHEDD, *Assistant Examiner.*

U.S. Cl. X.R.

52—230; 287—80