A tension cable essentially composed of a multiplicity of thin strips is clamped at one or more locations with freedom of slight relative slippage of the strips to equalize their stresses. At each clamping point the strips may be separated by interposed foils which may be constituted by parts of the strips of a similar cable or by the opposite ends of the same cable bent back upon itself. The clamping pressure may be partly absorbed by laterally projecting foil portions with interposed spacers having substantially the thickness of the strips. A terminal member embraced by an end of the cable may contribute to the clamping effect.
REINFORCING AND PRESTRESSING CABLE

Our present invention relates to a reinforcing and/or prestressing cable to be used, for example, in concrete construction.

Conventional cables subjected to mechanical stress essentially consist of a multiplicity of strands of generally circular cross-section, such as metal wires or plastic filaments, which may be twisted for greater strength but whose combined cross-sectional area is far less than the overall cross-sectional area of the cable with a consequent lowering of the mean tensile strength per unit area. Moreover, these strands contact one another only at isolated points, giving rise to localized stress concentrations. Finally, the design of terminal elements for anchoring such a cable to a concrete body or other associated structure is complicated and not always satisfactory.

It is, therefore, the general object of our present invention to provide an improved tendon cable which avoids the inconveniences referred to above.

A related object is to provide simple means for anchoring such a cable to a structure.

A more particular object is to provide a novel cable construction, essentially composed of a multiplicity of coextensive elements of low individual tensile strength, wherein means are provided for effectively distributing the loading stresses so as to avoid any local overstressing.

With these and other objects in view, a tension cable according to our invention consists essentially of a multiplicity of juxtaposed parallel strips or ribbons of flexible character, e.g. metallic or resinous, which are of substantially the same length and preferably but not necessarily the same width, these strips being clamped together at one or more locations so as to be longitudinally shiftable only to the extent permitted by their elastic deformability. These strips, each of which may have a thickness of as little as 0.1 mm, thus form a stack which in most instances will be of square or rectangular profile and which therefore can be easily guided in a similarly profiled channel of an associated structure. If a high degree of slidability is desired, the cable surface and/or the channel walls may be coated or lined with a low-friction material such as polytetrafluoroethylene (Teflon).

When the cable is clamped at several longitudinally spaced points, the relative mobility of its strips is further restricted while the applied tension is more evenly distributed, particularly if the clamping pressure allows for some relative slippage of the strips to enable their realignment under stress and to facilitate stress transfer between these points. Portions of the cable near a clamped extremity thereof may also be passed around curved high-friction guide surfaces having a secondary restraining effect. Such guide surfaces may be formed, for example, by a cylindrically curved anchor block embraced by the cable; alternatively, they can be constituted by the walls of an undulating or meandering channel.

Pursuant to a further feature of our invention, the strips are separated at the clamping point or points by interposed foils or leaves of like or different material preferably having the same order of thickness; these interposed foils may be the strips of a similar cable spliced to or intersecting the first cable, or the opposite ends of the same cable bent back upon itself. In many instances, it will be advantageous to let the inserted foils project transversely from the strips to fit into a clamping frame wider than the cable; in such a case, we prefer to separate the projecting foil ends by spacers or pads having substantially the same thickness as the strips, thereby not only preventing a deformation of the foils under clamping pressure but also absorbing part of this pressure so as to preserve a measure of mobility for the strips to facilitate stress equalization as noted above.

These and other features of our invention will be described in greater detail hereinafter with reference to the accompanying drawing in which:

FIG. 1 is a cross-sectional view of a cable according to the invention, taken on the line I—1 of FIG. 2 and showing a clamping stage;

FIG. 2 is a cross-sectional view taken on the line II—II of FIG. 1;

FIG. 3 is a perspective view of an assembly similar to that shown in FIGS. 1 and 2;

FIGS. 4 and 5 are graphs illustrating the longitudinal stress distribution in a cable according to the invention;

FIG. 6 is a cross-sectional view of a multiple clamp for a cable according to the invention, taken on the line VI—VI of FIG. 7;

FIG. 7 is a cross-sectional view taken on the line VII—VII of FIG. 6;

FIG. 8 is a perspective view of an assembly similar to that shown in FIGS. 6 and 7;

FIG. 9 is an elevational view of a cable terminal according to our invention;

FIG. 10 is a cross-sectional view taken on the line X—X of FIG. 9;

FIG. 11 is a view similar to FIG. 9, illustrating a modification;

FIG. 12 is another view similar to FIG. 9, illustrating a further cable terminal embodying the invention;

FIG. 13 is a cross-sectional view taken on the line XIII—XIII of FIG. 12; and

FIG. 14 is a cross-sectional view of a modified cable according to our invention.

In FIGS. 1 and 2 we have shown part of a cable embodying our invention, this cable comprising a multiplicity of elongate ribbons or strips 1 (e.g. of metal) which generally are in contact with one another over the major part of their length but which at the location illustrated are separated by interposed foils 2. The foils, which are shown to be of the same order of thickness as the strips, may consist of similar or dissimilar material and, in particular, could be the ends of like strips forming part of a substantially identical cable.

The strips 1 and the foils 2 are joined together under transverse pressure in a clamping device comprising a rectangular frame 3, a pair of plates 4 slidably held in the frame to serve as clamp jaws and several pairs of complementary wedges 5, 6 inserted between the plates 4 and the frame 3. The wedges 5, 6 have the profile of right triangles slidably contacting each other along their hypotenuse, the angle of inclination of their contact surfaces being, of course, less than their angle of friction.

Although several wedge pairs 5, 6 have been shown disposed side by side, a single pair may suffice particularly in the case of relatively narrow strips. In such
event the pressure plates 4, serving to distribute the stress exerted by the several wedge pairs, could be omitted.

Folios 2 could also be blade-like projections of a common terminal member, not further illustrated, to be secured to the cable by the clamp 3 – 6. In FIG. 3 I have shown the strips 1 separated by foils 7 extending transversely to the strips and projecting laterally therefrom. The projecting foil portions are interlaced with coextensive spacers or pads 8 which may or may not be of the same material and which have substantially the same thickness as the strips coplanar therewith. The rectangular stack formed by the elements 7, 8 and by the interlaced portions of strips 1 is received in a four-sided box 9 having a bottom 10 with a rectangular cutout; after the box has been slid upwardly (arrow A) to receive the stack, pressure is exerted on the outermost strips 1a in the direction of arrow B and C by clamping means which may take the form of distributing plates and wedge pieces similar to the elements 4 – 6 of FIGS. 1 and 2 (see also FIG. 7). This pressure is partly absorbed by the projecting ends of foils 7 and the associated spacers 8; the remaining pressure acts upon the strips 1, 1a to restrain the cable against longitudinal displacement by a tensile force to which it may be subjected. Other conventional pressure-exerting means, such as screws, springs or hydraulic or pneumatic jacks, may of course be used in lieu of the wedges 5, 6.

As more particularly illustrated in FIG. 7, the wedges 5, 6 may be separated from the stack 1, 7, 8 by a pair of distributing plates 11, similar to plates 4 in FIGS. 1 and 2, as well as a pair of elastic inserts 12 juxtaposed therewith. The inserts 12 may be, for example, undulating steel plates with vertical crests and troughs as viewed in FIG. 7; they could also be constituted by pads of rubber or other elastomeric material.

If the clamping assembly exerts upon a strip 1 a perpendicular force N, the tensile stress T required to cause slippage of the strip is equal to 2/N where f is the coefficient of friction. Thus, it is always possible to provide a clamping pressure sufficient to restrain the strips against slippage under any applied tension up to the breaking stress of the strip.

Nevertheless, the strip does experience a certain elongation between its clamp jaws whereby the tension applied to it on one side of the clamping point generates a progressively decreasing stress over the length of the clamped strip portion. This has been illustrated in FIG. 4 where tension T has been plotted against length L. Over the clamped length L0, the stress rises substantially linearly from 0 to a maximum T0 which corresponds to the applied tension. The rising stress over the length L0 is proportional to the slip between any elemental area of the strip and the stationary clamping surfaces.

The elongation of the strip due to this progressive slip should be limited, however, to prevent any excessive weakening of the strip at this point. Instead of a uniform application of clamping pressure throughout the length L0, therefore, we may apply the highest pressure in the vicinity of point 0 (where the tension is smallest) and to decrease this pressure toward the side where the tension originates. A reduced stress differential per unit of length can also be realized by extending the effective clamping area. Finally, it is possible to clamp the strip assembly at several longitudinally spaced points with freedom of limited slippage at the point or points closer to the tensioned cable terminal, such as arrangement resulting in the graph of FIG. 5. According to that graph, the tensile stress T first rises from 0 to a relatively low value T1 over a length L1, clamped at a location remote from the origin of tension; the stress then remains constant up to the second clamping area of length L2, where it rises to another intermediate value T2. At a third clamping station of effective length L3, the tensile stress reaches its final magnitude T3. It will be noted that the slopes of the graph of FIG. 5 are considerably lower than those of the graph of FIG. 4.

FIG. 6 illustrates a relatively compact assembly for stressing a cable according to the invention in the aforesaid manner by four clamping stages. These stages are constituted by four boxes 13a, 13b, 13c, 13d each forming part of a clamping assembly of the type described above with reference to FIG. 7. The frame portions 9 of the several boxes abut one another while their bottoms 10 are freely penetrated by the cable, the passages through these bottoms constituting the regions of constant stress shown in FIG. 5. If the cable formed by the strips 1 is to be tensioned from the left as indicated by the arrow T in FIG. 6, it will be convenient to clamp first the box 13e in position thereon, followed by the boxes 13b, 13c and 13d. Upon the application of tension, a certain amount of slippage occurs in the three last-mentioned boxes, the ultimate stress distribution being analogous to that shown in FIG. 5. With a cable passing through a channel in a rigid structure such as a pipe or a concrete beam, the box 13d may be placed in direct contact with such structure to anchor the cable to it and to hold the clamping assembly in position. The number of boxes may, of course, be increased or reduced at will.

In FIG. 8 we have shown another assembly which can be substituted, with similar effect, for the set of juxtaposed boxes shown in FIG. 6. The clamping device of FIG. 8 comprises a casing 15 with two sidewalls 15' formed along their confronting surfaces with transverse ribs 16. The recesses between these ribs accommodate the ends of foils 7, similar to those shown in FIGS. 3 and 7, together with the spacers 8 (not seen in FIG. 8) interlaced therewith. The sidewalls 15' may be interconnected at the bottom of the casing, although the latter could also be open at both ends; the longitudinal edges of these sidewalls are formed with threaded bores 17 designed to receive bolts 19 which pass through corresponding holes in a series of alternately wider and narrower brackets 18, 20. The bolts 19 passing through brackets 18 are engaged by nuts 19' holding these brackets under pressure against the stack of elements 1, 7, 8 within the casing; this pressure may be initially generated by the nuts themselves or may have been applied by a jack or the like, subsequently removed, with the nuts serving only as retaining elements. The brackets 18, 20 are U-shaped and embrace the housing walls 15' by their arms 18a, 20a. The package 1, 7, 8 lodged between any two pairs of ribs 16 confronts one of the wider brackets 18 for individual adjustment of the pressure exerted thereon; the narrower brackets 20, aligned with the ribs 16, bear upon intermediate
zones of the cable where the spacers 8 are omitted and where the foils 7 are foreshortened or absent; these brackets, accordingly, serve only to form a rigid connection between the wall members 15.

The housing wall 15" opposite brackets 18, 20 may be rigid with sidewalls 15' or may be secured thereto by screws similar to bolts 19 and nuts 19'; in either case, this wall 15" constitutes a second clamp jaw cooperating with the jaws 18 of the several juxtaposed clamping assemblies. Naturally, this wall could also be subdivided into individual brackets 18, 20 to help select the optimum clamping pressure for each stage.

As in the embodiment of FIG. 7, resilient means may again be provided for elastically applying the clamp jaws against the cable strips. Thus, we may insert compression springs such as Belleville washers 19" between the nuts 19' and the brackets 18 so that, with the bolts 19 effectively connected to the remote jaw 15", the two jaws are elastically biased toward each other.

FIGS. 9 and 10 illustrate the distribution of the stresses of several clamping stages over a curved surface whose frictional engagement with the cable affords a still more gradual transition between points of maximum and minimum stress. A terminal member or head 22 has a generally cylindrically convex peripheral surface embraced from one side by one set of strips 1A and from the other side by another set of strips 1B whose ends are interleaved with those of strips 1A over a substantial part of that curved surface. The several clamping stages are constituted by pairs of flat bars 24 that are pivoted to head 22 by pins 23 and carry bolts 25 traversing pressure plates 26 which are held in position by nuts 27. Elastic pads 26a are shown interposed between the plates 26 and the stack of strips 1A, 1B. It will be noted that the radius of curvature of head 22 progressively increases from an apex, enveloped by both groups of strips 1A, 1B, to the transverse bottom edge of the head where its periphery flattens out. The two sets of strips 1A, 1B could be part of a single cable bent back upon itself.

As shown in FIG. 11, the two sets of strips 1A, 1B may be combined in a channel 29 of an extension 28 of a modified head 22a, this channel being flared so as to converge in a direction away from head 22a. In this embodiment, the head 22a is curved over an arc substantially greater than 180° and is studded over substantially its entire periphery by clamping stages 23 - 27 as described above. Member 28 may be a block integral with or otherwise secured to head 22a.

As shown in FIGS. 12 and 13, the strips 1 of a cable according to our invention may be split into two groups hugging opposite walls of an undulating channel 32 formed in a block 30. These walls are of sinusoidal shape and form constrictions 36, 37, 38 separated by wider passages accommodating cylindrical inserts 33, 35 between the two cable halves. Block 30 may consist of several laminations or sections held together by transverse bolts 31. A pair of clamp jaws 40 co-operate with an interposed wedge 39 to engage the free ends of the two cable halves; jaws 40 may be cemented or otherwise secured to the block and are shown externally reinforced by a flat coil 41 of metal or the like enclosed in an ellipsoidal shell 42.

Advantageously, the insert 35 proximal to the clamp 39, 40 is fixedly mounted between the lateral walls 34 of channel 32 whereas the more remote insert 33 is freely movable between these walls, thereby allowing greater freedom of slippage to the cable portions engaged by it. The two strip assemblies alternatively curve about the bends of the channel walls and the inserts, contacting them along arcs α, β, Γ, γ, and δ. Thus, the total surface frictionally engaged by the cable strips equals the sum of the arcs (α + γ + δ + β + Γ). The terminal members shown in FIGS. 9 - 12 may again be placed directly in contact with a structure against which the cable is to be stressed.

If the channel or bore to be traversed by the cable is of round rather than square or rectangular cross-section, the width of the strips may be staggered to conform to its outline. This has been shown in FIG. 14 where strips 101, of like thickness but different widths, are interleaved with foils 107 and spacers 108 complementing them to a prismatic stack which can again be compressed in, say, a clamping box of the type illustrated in 3, 6, 7. Beyond the stack, the cable constituted by the foils 101 is of generally cylindrical configuration so as to be easily guided in a round bore of corresponding diameter.

Thus, whether the profile of the cable be round or polygonal, its cross-sectional area can always be substantially fully occupied by tensile elements for maximum tensile strength.

We claim:
1. A cable junction comprising:
   a first cable portion and a second cable portion each composed essentially of a multiplicity of flat, superposed and substantially longitudinally coextensive strips, the strips of said first cable portion having extremities interleaved with extremities of the strips of said second cable portion in direct broad-surface contact throughout a predetermined zone of overlap;
   a body with a curved guide surface hugged by an outermost one of said strips in said zone of overlap;
   and a plurality of clamps engaging said said strips at longitudinally spaced locations and bearing upon said interleaved extremities under transverse pressure exerted against said body.
2. A cable junction as defined in claim 1 wherein said body forms part of a terminal member and has a generally cylindrically convex surface embraced by a terminal portion of said strips.
3. A cable junction as defined in claim 2 wherein the strips of said cable portions are wound about said convex surface in opposite directions.
4. A cable junction as defined in claim 3 wherein said terminal member has an extension of said body formed with a channel converging in a direction away from said convex surface, said strips passing through said channel and merging therein into a single cable.
5. A cable junction comprising:
   a first cable portion and a second cable portion each composed essentially of a multiplicity of flat, superposed and substantially longitudinally coextensive strips, the strips of said first cable portion having extremities interleaved with extremities of the strips of said second cable portion in direct broad-surface contact throughout a predetermined zone of overlap;
and resilient clamping means yieldably bearing upon said interleaved extremities under transverse pressure over part of said zone, said clamping means comprising a pair of jaws and at least one elastic insert between said jaws and said strips.

6. A cable junction comprising:
a cable bent back upon itself and composed essentially of a multiplicity of flat, superposed and substantially longitudinally coextensive strips with opposite extremities interleaved in direct broad-surface contact throughout a predetermined zone of overlap;
and clamping means bearing upon said interleaved extremities under transverse pressure over part of said zone.

7. A cable junction comprising:
a first cable portion and a second cable portion each composed essentially of a multiplicity of flat, superposed and substantially longitudinally coextensive strips, the strips of said first cable portion having extremities interleaved with extremities of the strips of said second cable portion in direct broad-surface contact throughout a predetermined zone of overlap;
and clamping means bearing upon said interleaved extremities under transverse pressure over part of said zone.

* * * *
UNIVERS STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,701,554
DATED : 31 October 1972
INVENTOR(S) : André PUYO and Pierre André HABIB

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading, line 1737, after the situs of the Assignee, read:

-- Assignee of one half (50%) and Pierre André HABIB, Paris, FRANCE, Assignee of one half (50%) -- .

Signed and Sealed this

nineteenth Day of August 1975

[SEAL]

Attest:

RUTH C. MASON Attesting Officer

C. MARSHALL DANN Commissioner of Patents and Trademarks