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CABLES FOR PRESTRESSING CONCRETE

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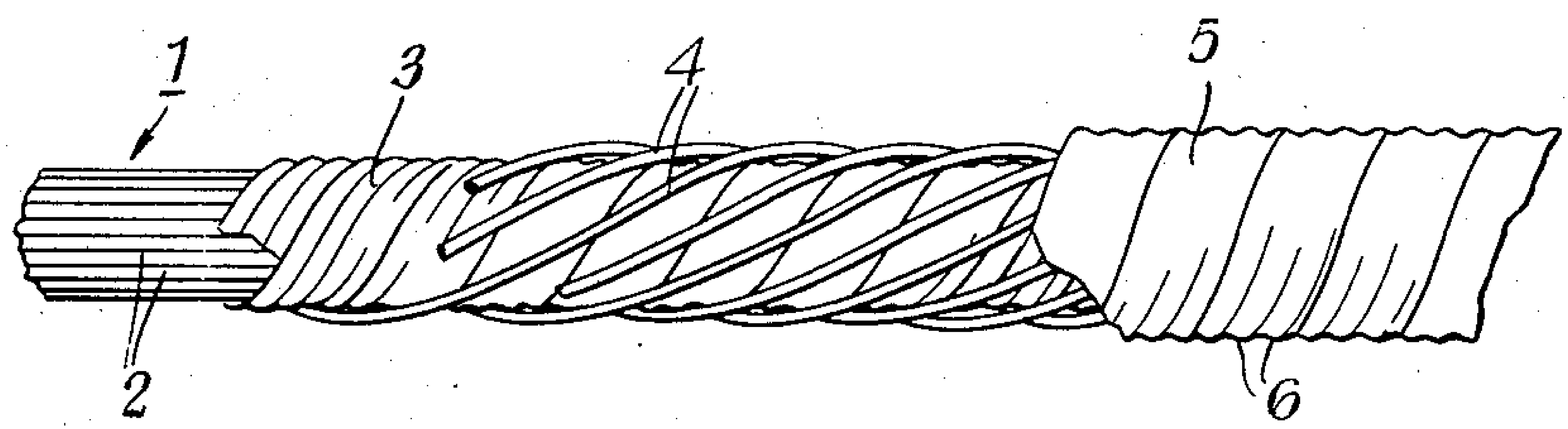

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CABLES FOR PRESTRESSING CONCRETE

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The present invention relates to pre-stressing members for use in pre-stressed concrete constructions.

Pre-stressing forces are commonly applied to concrete members by a technique known as post-tensioning. In one common application of this technique, pre-stressing members comprising one or more high tensile steel wires, or tendons consisting of a bundle of wire side-by side, or solid bar or strand of steel wire rope are placed in position and the concrete, of which the concrete member is to be formed, is cast around the wires or tendon. When the concrete has gained sufficient strength, the tendons are tensioned by a jack or other means, and are then anchored at their ends to the concrete member so that the tension within the wires or tendons causes a resultant compressive pre-stressing force in the concrete member.

When the wires or tendons are tensioned, it is necessary for them to move relatively to the surrounding concrete. To allow this movement to take place, each wire or tendon is initially surrounded by a sheath which supports the concrete when it is cast and prevents it from bonding to the wire or tendon. When the wire or tendon is tensioned, it moves within the sheath. Some of the prestressing force applied by the jack or other force-applying means to the wire or tendon is absorbed in the frictional drag between the wire or tendon and the sheath. If the wire or tendon is tensioned by a jack at each end, the proportion of the total force thus absorbed increases to a maximum midway of the length of the tendon. Thus, the force in the tendon at its mid-point may be considerably less than the force applied at its ends.

In practice, in the case, for example, of a simply supported beam, the pre-stressing force is required to be a maximum at the centre of the length of the beam, and, therefore the loss of pre-stressing force due to friction between the wire or tendon and its surrounding sheath, is a great disadvantage and must be reduced as far as possible.

However, after the wire or tendon has been tensioned and anchored, it is necessary to provide as effective a bond as possible between the wire or tendon and the sheath so that should there be any failure or slipping of the anchorage, the wire or tendon will be maintained in its state of tension due to the bond between the wire or tendon and the surrounding concrete through the sheath. This bond provides an added margin of safety to the concrete member. Moreover it is found that a good bond between the pre-stressing wires or tendons and the concrete reduces the size of cracks if the member is overloaded and increases the load necessary to cause complete rupture of the member.

The difficulty of providing for both a small loss of pre-stressing force due to friction when the wire or tendon is tensioned, and also an adequate bond between the surface of the wire or tendon and the sheath after tensioning lies in the incompatability of providing a single surface both with good sliding qualities and also good bonding qualities. A good sliding surface will normally require a lubricant, and the cheapest and most convenient way of establishing a bond between the surface of the wire or tendon and the surrounding sheath is to inject cement grout, which is a mixture of hydraulic cement and water, into the space between the wire or tendon and its sheath. It is difficult, however to find a lubricant which does not effectively inhibit the bond between the lubricated surface and the injected grout. Even the so-called soluble lubricants do not dissolve satisfactorily in

the grout and traces of the lubricant usually remain on one of the mutually engaging surfaces and such traces are sufficient to impede or destroy the bond.

The necessity of providing good sliding qualities between the surface of the wire or tendon and its surrounding sheath during tensioning is particularly important in cases where the wire or tendon lies in a curved path within the concrete member. Placing of the wires or tendons in a curved path is, however, particularly advantageous in deep beams, and where several spans are continuous, an undulating wire or tendon is the most economic. The curved path, however, causes lateral forces of considerable magnitude to be applied to the wire or tendon when it is tensioned from its ends, which forces result in considerable friction opposing relative sliding of the wire or tendon and the surrounding sheath.

The establishment of good bond between the wire or tendon and the surrounding sheath and thus with the concrete enveloping the sheath, is of particular importance when the design load of the concrete member is exceeded and rupture of the member takes place. If there is no bond, it is impossible to greatly increase the stress in the wire or tendon as deflection of the concrete member increases and, therefore, this deflection will increase until rupture of the concrete takes place without the metal of the wire or tendon even approaching its own rupture stress. If there is a bond, however, the stress in the metal is increased as the concrete member deflects and in this way, it is possible to achieve as much as thirty percent increase in the total load-bearing capacity of the member before total failure occurs.

It is an object of the present invention to provide a means whereby the friction between the prestressing wire or tendon and its surrounding sheath is small during the process of tensioning and whereby a satisfactory bond may be established between wire or tendon and sheath after tensioning and anchorage of the wire or tendon.

According to the present invention there is provided a pre-stressing member for use in pre-stressing concrete, which member comprises a wire or tendon surrounded with an openwork layer of material which is either self-lubricating or is coated with a boundary lubricant and a sheath surrounding the said layer so that enclosed spaces are formed between the wire or tendon and the sheath which can be filled with a bonding substance such as cement grout which thereby comes into contact with the respective opposed surfaces of the wire or tendon and the sheath.

Thus, when the wire or tendon is being tensioned, it is supported only by the open work layer which provides a lubricated sliding surface, but after the wire or tendon has been tensioned, grout can be injected between the wire or tendon and the sheath to fill the space which is not occupied by the open work layer. The surface of the sheath and of the wire or tendon in this space is not contaminated with lubricant and, therefore, a satisfactory bond can be obtained.

Various materials are satisfactory for forming the open work layer. For example, it may consist of wire or strip made of lead, polytetrafluorethylene, or graphite-filled plastic, or wire or strip coated with lead, graphite or polytetrafluorethylene. Alternatively, the open work layer may consist of an open mesh fabric, for example of the type known as braiding, formed of self-lubricating filaments made, for example of wax-filled polyvinyl chloride or nylon. It may also consist of a layer of what is commonly known as expanded metal, or again of a layer of knitted wires of fibres. It may also consist of a wire or strip of molybdenum so treated as to have a thin surface layer of molybdenum di-sulphide which is an extremely good boundary lubricant, or a high tensile steel wire from which the wire drawing soap has not been removed.

The presence of the open work layer between the wire or tendon and the sheath results in a great reduction in the friction there-between and for example the coefficient of friction of steel on polytetrafluorethylene is of the order of that of wet ice on ice and is approximately only one-tenth of that of dry steel on dry steel.

It will be noted that the lubrication is of the "boundary" type, where the lubricating layer is extremely thin. Lubrication of the type where a layer of fluid is maintained between the two surfaces is not practicable for the purposes of the present invention on account of the high pressures caused by curvature of the wire or tendon and of the low velocity of movement.

Previously when it was required to reduce the friction between a pre-stressing tendon and its surrounding sheath and later to grout up the space therebetween and form a satisfactory bond, it was necessary to make the bore of the sheath larger than the cross section of the tendon so that the sheath was unsupported from the tendon, and in consequence the sheath had to be stout enough to maintain its shape without any support from the tendon when the surrounding concrete was placed in position.

With the construction according to the invention, however, the open work layer is wrapped directly around the tendon and the sheath is supported on this layer, the only limitation being that the spacing of the members of the open work layer and the stiffness of the sheath should be such that the sheath is not forced under the pressure of the surrounding concrete into contact with the tendon in the spaces of the open work layer. Since the sheath may be supported at closely spaced points by the open work layer, it may be made of much lighter material than has previously been possible. It is not even essential that the sheath should be impervious to water provided it prevents the passage of cement particles from the surrounding concrete into the space between the sheath and the tendon, since if water penetrates into this space it will drain away along the length of the tendon.

When however the open work layer is constructed of lubricating members such as polytetrafluorethylene which are expensive, there may be economic advantage in reducing the number of such members to a minimum, for example three, and in such case the sheath will need to be nearly as thick as an unsupported sheath and will require to be wrapped on around extra wires, which are withdrawn progressively as the winding proceeds, in order to maintain the space between the sheath and tendon where the sheath does not bear on the lubricating wires.

One example of a pre-stressing member constructed in accordance with the invention is shown in the sole FIGURE of the accompanying drawings and comprises a tendon **1** formed of a bundle of high tensile steel wires **2** arranged in an approximately circular disposition and having the interstices between the wires filled with a hardenable filler material in an unhardened condition, such as for example dry cement, as described in the specification of co-pending patent application No. 819,609, filed on June 11, 1959, now U.S. Patent No. 3,060,640, granted October 30, 1962. This bundle of high tensile steel wires is tightly wrapped with a helical binding wrapping **3** of steel strip which may be corrugated, wound on to the bundle under tension. On to the wrapping **3** there is applied an open work layer formed of lubricating wires **4** made of one of the materials hereinbefore mentioned and spaced one from another at a slight inclination to the high tensile steel wires. The wires **4** are spaced at equal peripheral distances around the wrapping **3** and are surrounded by a sheath **5** consisting of a further helical wrapping of steel strip, which, as it is wound on, passes through rollers which form in it lonigtudinal corrugations as shown at **6** which stiffen it and improve the bond between it and the surrounding concrete.

In using the member it is first positioned as required in the mould in which the concrete is to be cast. The concrete is then poured into the mould and when it has set

sufficiently to withstand the prestressing force, the ends of the tendon **1** are gripped by suitable tensioning means such as for example hydraulic jacks and the required tension applied. During such tensioning the relative sliding between the wrapping **3** and the sheath **5** is facilitated by the lubricating wires **4**.

The ends of the tendon are then anchored in known manner, and cement grout is injected at one or both ends of the member between the layer **3** and the sheath **5** so that it flows along the member and fills all the spaces between the wires **4**, and upon setting bonds the layer **3** to the sheath **5**. At the same time, water is injected into the tendon **1** at one or both ends thereof to moisten the dry cement filling the interstices between the wires **2** and which upon hardening firmly bonds the wires one to another and to the layer **3**.

It will be noted that metallic strip other than steel may be employed and where an excellent bond is essential, aluminium strip may be used since this reacts chemically with the cement in the tendon and in the cement grout injected between the layer **3** and the sheath **5**. In addition, it provides excellent protection against corrosion of the steel wires since in any electrolytic action, the aluminium is sacrificed and deposited on the steel.

It is in general desirable that the lubricating wires should not be exactly parallel to the wires in the tendon since the tendon will bear on the lubricating wire and it is desirable to avoid any risk of bursting the wrapping around the tendon. Just as soon as the lubricating wire moves around the tendon in a helix, this danger is largely averted.

When the lubricating wires are applied helically, the pitch of the helix is preferably different from that of both the steel strip wrappings forming the internal layer **3** and the external sheath **5** respectively.

Instead of applying a first wrapping of steel strip under tension to the bundle of high tensile steel wires as above described, a wrapping of fabric, for example glass fibre or linen, may be used, in which case a further binding of wire may be applied over the wrapping to give resistance to abrasion caused during handling.

In a further example of pre-stressing member according to the invention, the lubricating wires run parallel to the high tensile steel wires of the tendon, but are closely spaced, for example at one eighth inch centres, and the external wrapping forming the sheath, being thus supported at closely spaced points, is formed of fabric wound on under tension. Again in this construction, the outer fabric wrapping may be protected by an external wire binding. In yet another construction, the corrugated steel strips forming the wrapping **3** and the sheath **5** respectively are wound on in helices of different pitch or of opposite hand and the lubricating wires **4** are replaced by a tape formed of open mesh lubricating material and wound on between the two wrappings of steel strip.

Alternatively the open work layer may be formed by a wire wrapped helically on the inner wrapping the wire itself not being lubricated, and the outer surface of the inner wrapping and the inner surface of the outer wrapping are coated with a dry lubricant. The corrugations of the steel strips provide mechanical interlock with the hardened cement grout to ensure adequate bonding.

Conveniently the high tensile steel wires in the tendon may be given a slight twist of about one turn in a thirty foot length of tendon to enable the tendon to be coiled without over-straining any of the wires.

When the open work layer is formed of helically wound lubricating wires, the pitch of the wires must not be too close in order not to length inordinately the path of the grout when it is injected from one end. This requirement is satisfied in general terms if each lubricating wire makes one complete turn in a length of the order of three or four diameters of the tendon on which it is wrapped.

In using the pre-stressing member according to the invention, the bond between the tendon and the sheath may be enhanced if the grout or other bonding material which is injected between the tendon and the sheath is such that it expands slightly on setting. One example of such a bonding material is Portland cement mixed with aluminium powder.

It will be understood that the term "wire" as used in the expression "wire or tendon" employed throughout the present specification and in the appended claims, is intended to include a solid steel bar or a steel wire rope.

What I claim is:

1. An elongate prestressing member for use in prestressed concrete construction comprising an elongate central tendon, a tubular sheath surrounding said tendon and substantially coextensive therewith and an open work intermediate layer positioned between said tendon and said sheath, said layer being formed of relatively rigid self lubricating material to engage said sheath and tendon to maintain them spaced and being formed to have at least one uninterrupted open passageway extending for substantially the length of the layer which is adapted to receive a liquid grout to bond the tendon to the sheath after tensioning of the member.

2. The invention as defined in claim 1 in which the open work layer is formed by a plurality of wires spaced apart and around the periphery of the tendon to form uninterrupted passageways therebetween.

3. The invention as defined in claim 1 in which the open work layer is formed by a plurality of helically wound wires spaced apart and around the tendon to form uninterrupted passageways therebetween.

4. The invention as defined in claim 1 in which the central tendon consists of a bundle of wires and a binding wrapping enclosing the wires.

5. The invention as defined in claim 4 in which the

binding wrapping and the sheath are formed from wound steel strip.

6. The invention as defined in claim 4 in which the binding wrapping and the sheath are each formed from helically wound steel strip, the directions of the helices being of the opposite hand.

7. The invention as defined in claim 4 in which the binding wrapping and the sheath are formed from wound steel strip, and in which longitudinally directed corrugations are formed.

8. The invention as defined in claim 1 in which the open work layer is formed from a material selected from the group consisting of lead, polytetrafluorethylene, graphite filled plastic, wire coated with lead, strip coated with lead, mesh fabric formed of filaments of wax filled polyvinyl chloride, mesh fabric of nylon, wire coated with molybdenum di-sulphide and strip coated with molybdenum di-sulphide.

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