United States Patent

Lang

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[54] **TENDONS FOR PRESTRESSED CONCRETE AND PROCESS FOR MAKING SUCH TENDONS**

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[52] **U.S. Cl.** **57/149,** 57/153, 57/162, 57/164, 117/75

[51] **Int. Cl.** **D07b 1/16,** D07b 7/14

[58] **Field of Search** 57/139, 145, 149, 153, 156, 57/162, 164; 117/75, 128; 52/230

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[57] **ABSTRACT**

A tendon suitable for posttensioning concrete and for use in other applications comprising a multiple-wire strand incased in a corrosion inhibitor in an amount sufficient to provide a circular enclosure greater than the outside diameter of the strand and having a seamless plastic jacket tightly covering said incased strand. A process of making said tendon which comprises the steps of coating and filling the interstices of a multiple-wire strand with a corrosion inhibitor, passing same through a circular die of a diameter greater than the strand to remove excess corrosion inhibitor and to form a circular enclosure of said inhibitor around said strand, and melt extruding a plastic jacket around said incased strand.

9 Claims, 3 Drawing Figures

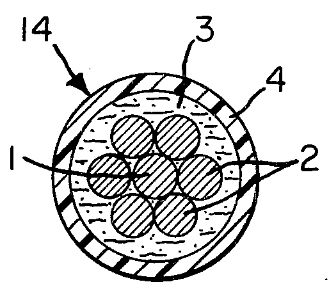


FIG. 2

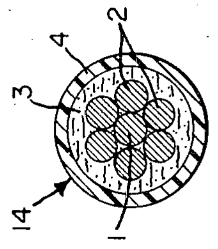


FIG. 1

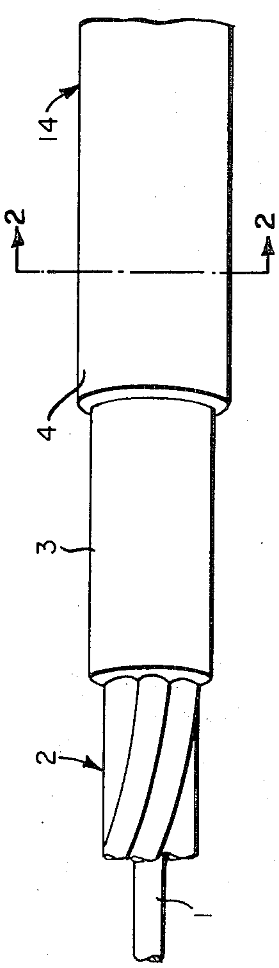
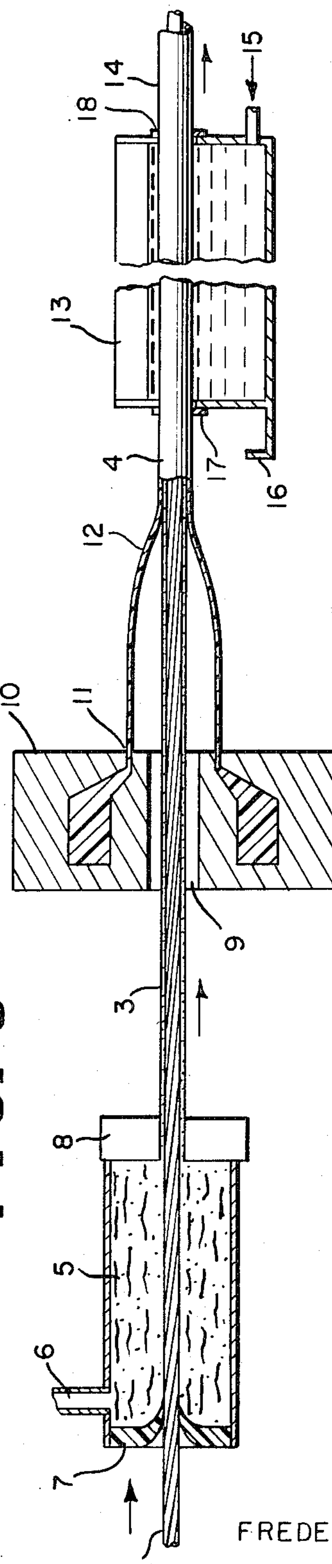


FIG. 3



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TENDONS FOR PRESTRESSED CONCRETE AND PROCESS FOR MAKING SUCH TENDONS

This invention relates to tendons suitable for posttensioning concrete structures and to a process for making such tendons.

Tendons placed in a form which defines the shape of the concrete structure and which tendons can be elongated to a point within their elastic limit after the concrete hardens and thereafter fixed in the elongated state to produce compressive force or prestress in the concrete are known as posttensionable tendons. The process is known as prestressing of concrete by posttensioning. Important to the success of posttensioning is the desire that the tendon be free to move within the hardened concrete so that the tensile load is distributed evenly along the length of the tendon. For instance, nuclear power plants usually include large containment vessels made of concrete to withstand internal pressure. Some of these vessels have tendons that pass 180° or 270° around the vessel in the hoop direction and it is desirable that these tendons have as even a distribution of elongation as possible. Tendons are useful without concrete for many applications including buoys at sea and cable roof structures.

Steel rods, wire and multiple-wire strands, used for posttensioning of concrete, have been grease coated and then helically wrapped with paper or plastic tapes. The multiple-wire strand has been preferred when the diameter of the steel component exceeds about 0.3 inch because it has better handling characteristics.

It has become the practice to helically wrap wire around the taped tendon to stabilize and fix the tape wrapping so that it would remain in place during shipping, placing and use. Other attempts have been made to improve the tendon made from multiple-wire strand such as using a polyvinyl chloride tape and heat or solvent sealing the seam along the length of the strand. The jacket of this latter product has tended to split at the seams during handling, creating additional corrosion problems. Furthermore, the presence of air pockets between the tape and the strand expose the tendon to corrosion.

Difficulty has been experienced in obtaining uniform elongation during posttensioning with tendons that have curvature along their length of 180°, or greater. For example, the best multiple-wire strand product known in the prior art when passed circumferentially around one-half of a circular vessel will have only 65 percent of the tensile load transmitted from the jacked end to the unjacked end when the load at the jacked end exceeds 50 percent or more of the strands breaking strength.

The present invention provides a stranded multiple-wire tendon which overcomes many of the disadvantages of the previous stranded multiple-wire tendons. The present invention also provides in some of its embodiments a stranded tendon that gives more uniform elongation during posttensioning than previously known with commercially available stranded tendons when the curvature along the tendon is 180° or greater. The present invention provides a tendon having increased reliability and increased assurance of trouble-free service prior to, during and following its installation. The tendon of this invention comprises a stranded multiple-wire component incased in a corrosion inhibitor, having greaselike consistency, particularly relative to worked penetration and flow characteristics, in an amount sufficient to provide a circular incasement around the strand of at least two mils greater in diameter than that of the strand and having a seamless plastic jacket tightly covering said corrosion inhibitor incased strand.

This invention also includes the process of making said tendon which comprises incasing a multiple-wire strand with a corrosion inhibitor having greaselike properties, particularly relative to worked penetration and flow characteristics, smoothing and shaping said corrosion inhibitor so as to provide an incasement having a circular surface around the strand, the diameter of the circle being at least 2 mils greater than the diameter of the strand, and melt extruding and shrinking a seamless plastic tubular jacket around said incased strand to provide a tight jacket, thereby substantially excluding air and gas from between the jacket and the corrosion inhibitor.

An embodiment of the product and process of this invention is illustrated in the accompanying sheet of drawings in which:

FIG. 1 is a side view showing the components of a tendon;

FIG. 2 is a cross section taken on line 2—2 of FIG. 1; and

FIG. 3 is a diagrammatic view of a process for making the tendon.

Referring to FIGS. 1 and 2, the tendon 14 contains a multiple-wire strand composed of a center wire 1 and six helically wrapped wires 2. The strand is incased in a corrosion inhibitor 3 that fills all spaces within the strand and around it providing a circular enclosure of corrosion inhibitor of greater diameter than that of the strand. The incased strand is jacketed with a tight seamless plastic jacket 4 to provide the novel tendon. The diameter of the circular incasement of the corrosion inhibitor should be at least 2 mils greater than the diameter of the strand. The plastic jacket should be sufficiently thick to resist puncturing of the jacket during shipping and handling of the tendon as well as during the placing of the tendon and the pouring of the concrete.

FIG. 3 illustrates a process for making the novel tendon. In this process a multiple-wire strand 2 is passed into pressure chamber 5 into which a corrosion inhibitor is fed under pressure through inlet 6. A tetrafluoroethylene polymer guide and grease retaining bushing 7 centers the strand and prevents the escape of corrosion inhibitor. The pressure of the corrosion inhibitor is adjusted so that it penetrates and fills the voids in the strand. A circular die 8 smooths and shapes the corrosion inhibitor so that it forms a circular incasement 3 about the strand 2. The incased strand is then passed through the throat 9 of a tubing die 10. Molten thermoplastic polymer 11 is extruded as a tube around said incased strand. The rate of travel of the strand and the rate of extruding of the thermoplastic polymer is adjusted so that there is a necking down 12 of the polymer at a distance from the die 10 that will permit the cooling of the polymer to a temperature below the vaporization temperature of the corrosion inhibitor. By this process the plastic polymer shrinks and forms a tight seamless plastic jacket 4 around said incased strand substantially excluding air and gas from between the jacket and the corrosion inhibitor.

In the commercial practice of the process it is preferable that the jacket be rapidly cooled and hardened so that the tendon 14 can be wound onto a spool for storage, or shipping. Any method of cooling and any cooling medium may be used as long as it is compatible with the jacket. In the process of FIG. 3 the plastic-jacketed tendon is passed into a water cooling tank 13, cold tap water enters the tank through pipe 15 and overflows into tank 16. Slotted polyurethane sponge guides 17 and 18 maintain the water level so that it covers the tendon 14, thereby effectively cooling and hardening the plastic jacket.

The multiple-wire strand may be of any form. However, strands currently in use are those having one straight center wire and six wires helically wrapped in one direction to cover the center wire. The "diameter" of the strand used herein and in the claims is the diameter of the circle that touches the outside surface of the wrapped wires. For the posttensioning of concrete, strands of about 0.30 inches to about 0.75 inches in diameter are used, the upper limit being dictated by the ease of handling the tendon. Most strands in use vary in diameter from 0.375 to 0.625 inches. It is preferable that the wire strands be of high-tensile steel, having a breaking strength of at least 200,000 p.s.i.

The strand may be used in the form received from the manufacturer or its outer surface can be cleaned or polished by using abrasive-impregnated polishing wheels. The strand may also be coated with a thin layer of a solid lubricant, especially polytetrafluoroethylene or a copolymer of tetrafluoroethylene and hexafluoropropylene containing 5 to 35 percent hexafluoropropylene. Such a coating can be applied to the outer surface of a cleaned strand or a polished strand by coating the surface with an aquasol or organosol of the polymer and thereafter drying said coating and heating same to the fusion temperature of the polymer, usually in the range of 600° to 700° F.

The incasement of corrosion inhibitor is molded directly into the interstices and over the strand to a diameter greater than the strand. This may be accomplished by passing the strand through a chamber into which the corrosion inhibitor is fed under pressure and through a circular die of a diameter at least two mils greater than the diameter of the strand. The incased strand is then passed through the annular throat of a melt extrusion tubing die having an inside diameter which provides at least a 0.050 inch diametral clearance outside the incased strand. By controlling the rate of travel of the strand and the rate of extrusion of the plastic, the plastic tubing is necked down over a distance sufficient to cool the tubing to a temperature below the vaporization temperature of the corrosion inhibitor at the point of contact with the corrosion inhibitor. By this process air and other gases are substantially excluded from the tendon and a uniform seamless tight plastic jacket is created that maintains the strand in the incasement of the corrosion inhibitor.

The plastic used in making the jacket can be any thermoplastic polymer having the following properties: low permeability to air and moisture, high-tensile strength, and high stability in its chemical and physical properties. The polymer employed for the jacket must exhibit a saturation moisture content at ambient conditions, usually room temperature of about 25° C., of less than 8 weight percent. Useful polymers include the polyolefins prepared from one or more olefins having 2–10 carbon atoms, the polyamides formed from hexamethylenediamine and sebacic acid, normally referred to as a 610 nylon, the fluorocarbon polymers, and the vinyl polymers. The polyolefins, especially high molecular weight polyethylene polymers, and the polymers and copolymers of propylene, are particularly useful. The thickness of the molten polymer as extruded should be such that the resulting tubing wall is at least 6 mils thick, preferably 10 to 25 mils thick, when using polypropylene.

The corrosion inhibitor should have greaselike properties, particularly the properties relative to the ability of the corrosion inhibitor to stay put and adhere to the strand. This includes all noncorrosive greases, greases that have corrosion inhibitor additives and corrosion inhibitors having greaselike consistency. This latter includes liquid corrosion inhibitors that have been thickened to give the consistency of a grease. The corrosion inhibitor should have substantially the same ASTM worked penetration values as that of grease, namely values within the range of 85 to 385 at 77° F. as determined by the ASTM D217 method. The corrosion inhibitor should be of a consistency that will maintain a uniform outside circular shape when passing through the incasement die and until the plastic jacket is applied.

Two products that meet the above requirements for the corrosion inhibitor are Union Oil Company's Unoba A–2 and Humble Refining Company's Lidok 2. The first is a fibrous-textured barium soap grease with a paraffinic base oil and the other is a buttery-textured lithium soap grease with a naphthenic base oil. Both contain oxidation inhibitors. These products have ASTM worked penetration at 77° F. of 270 and 280, respectively. Rust and corrosion protection is provided by the barium and lithium soaps and chemical additives. Another product is that obtained by thickening the liquid corrosion inhibitor disclosed and claimed in U.S. Pat. No. 3,443,982 of E. W. Kjellmark, Jr. granted May 13, 1969. This corrosion inhibitor can be thickened by mixing it with about 10 percent carboxy methyl cellulose, to give a product that has a worked penetration value within the range of grease.

The following examples are given to illustrate but not limit the invention.

EXAMPLE I

A multiple-wire strand, 0.375 inches in diameter made from seven high-tensile steel wires is processed in accordance with the process described above relative to FIG. 3. The strand is in the form as received from the manufacturer and has a breaking strength of 270,000 p.s.i. The strand is passed through a pressure chamber fed with the corrosion inhibitor, Unoba A–2. The circular incasement die at the end of the chamber has a diameter 10 mils greater than that of the strand. The corrosion inhibitor is fed into the chamber under sufficient pressure to fill the strand interstices and in an amount sufficient to coat said strand so that the die will remove excess corrosion inhibitor, leaving a uniform circular incasement of corrosion inhibitor around and covering said strand. The corrosion inhibitor incased strand is fed through the center of the annular throat of a melt extrusion tubing die having a diametral clearance of 0.1 inches outside the incased strand. Polypropylene is melt extruded as a tubing around said strand. The rate of travel of the strand and the rate of extruding of the polypropylene is controlled so that there is a necking down of the polypropylene tubing over a distance of 2 to 3 inches from the throat of the tubing die to the point of contact with the corrosion inhibitor on the strand. At this point the temperature of the polypropylene tubing is below the vaporization temperature of the corrosion inhibitor. The tubing is rapidly cooled and hardened by passing the tendon into a water bath. Thereafter the tendon is wound onto a spool.

The above tendon was tested as follows to determine its uniformity of elongation when placed under tension in an arc. A 200-foot length of said tendon was embedded circumferentially around half of a circular concrete vessel having a diameter of approximately 125 feet with the ends of the tendon protruding tangentially from the vessel through load bearing plates. After the concrete hardened, a jack was attached at one end and a load of 16,000 lb. was imposed on the tendon. This load is 190,000 p.s.i. A load cell was used to determine the load at the unjacked end. It was found that 78 percent of the load at the jacked end was transmitted to the unjacked end.

EXAMPLE II

Example I was repeated with the single exception that the strand as received from the manufacturer was first polished with abrasive-impregnated polishing wheels to give an exceptionally smooth outer surface to said strand before applying the corrosion inhibitor. The tendon obtained was tested in the same manner as the tendon of Example I and the load cell indicated that 85 percent of the load at the jacked end was transmitted to the unjacked end.

EXAMPLE III

Example I was repeated with the single exception that the strand prior to applying the corrosion inhibitor was processed as follows. The outer surface of strand as received from the manufacturer was polished as in Example II with abrasive-impregnated polishing wheels to give a smooth outer surface. This smooth outer surface was then coated with a thin layer of an organosol of the copolymer of tetrafluoroethylene and hexafluoropropylene containing 5 to 35 percent hexafluoropropylene. The coating was then dried and thereafter heated to the fusing temperature of the copolymer, e.g., between 600° and 700° F.

The strand with a thin outer coating of the copolymer is then made into a tendon by the process of Example I. The tendon obtained was tested in the manner as was the tendon of Example I and the load cell indicated that 89 percent of the load at the jacked end was transmitted to the unjacked end.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that this invention is not limited to the specific embodiments thereof except as defined in the appended claims.

I claim:

1. A tendon suitable for posttensioning concrete and for use in other applications comprising a multiple-wire strand incased in a corrosion inhibitor, having greaselike consistency relative to worked penetration, in an amount sufficient to pro-

vide a circular incasement around the strand of a diameter at least 2 mils greater than the diameter of the strand, and having a seamless plastic jacket tightly covering said incased strand.

2. The tendon of claim **1** which allows tensile loading along its length during posttensioning such that a 200-foot long tendon passing circumferentially around one-half of a circular vessel has at least 75 percent of the tensile load transmitted from the jacked end to the unjacked end when the load at the jacked end exceeds 50 percent or more of the strand's breaking strength.

3. The tendon of claim **1** in which the multiple-wire strand is of high-tensile steel and the plastic jacket is a polymer or copolymer of propylene.

4. The tendon of claim **1** in which the multiple-wire strand is of high-tensile steel and the plastic jacket is of a high molecular weight polyethylene.

5. The tendon of claim **1** in which the multiple-wire strand is of high-tensile steel and has on its outer surface a thin coating of a polymer selected from the group consisting of tetrafluoroethylene and copolymers of tetrafluoroethylene with 5 to 35 percent hexafluoropropylene.

6. A process for making a tendon suitable for use in the posttensioning of concrete and for use in other applications which comprises incasing a multiple-wire strand with a corrosion inhibitor having greaselike consistency, particularly relative to worked penetration and flow characteristics, smoothing and shaping said corrosion inhibitor so as to provide an incasement having a circular surface around the strand, the diameter of the circle being at least 2 mils greater than the diameter of the strand, and melt extruding and shrinking a seamless plastic tubular jacket around said incased strand to provide a tight jacket.

7. The process of claim **6** in which the multiple-wire strand is of high-tensile steel and the plastic is a polymer or copolymer of propylene.

8. The process of claim **6** in which the multiple-wire strand is of high-tensile steel and the plastic is a high molecular weight polyethylene.

9. The process of claim **6** in which the multiple-wire strand is of high-tensile steel and has on its outer surface a thin coating of a polymer selected from the group consisting of tetrafluorethylene and copolymers of tetrafluorethylene with 5 to 35 percent hexafluoropropylene.

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