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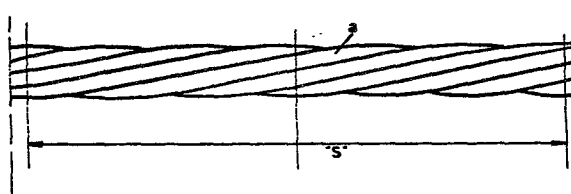
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Prestressing strand for concrete structures and concrete structures containing such strand.

In a prestressing strand for use in stressing a concrete structure, having one or more central core wires and a plurality of outer wires extending helically around the core wire the surface of at least the core wires is modified in order to increase the friction resistance to relative movement between the core wire and the outer wires. This strand is found to give more accurate stressing, where the conduit in the concrete for the tensioned wire is curved. The outer wires may also have modified surfaces. The modification may be mechanical indentations or surface conditioning treatment such as oxidation, etching, coating or deposition.



EP 0 078 564 A2

"Prestressing strand for concrete structures and
concrete structures containing such strand"

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The invention relates to prestressing strand for use in a concrete structure, comprising at least one central core wire and a plurality of outer wires
5 extending helically along the core wire to envelop it. Such strands are often used as the tensioned reinforcing elements in prestressed concrete structures, in which they may for example be inserted in curved
10 conduits in the concrete structure. The conduits are formed for example by tubes of steel or another material, which are pre-cast into the concrete structure. The invention also relates to a process of manufacturing such strand and to a concrete structure
15 containing such strand.

2. DESCRIPTION OF THE PRIOR ART

A commonly used type of prestressing strand comprises six equally thick outer wires and one single core wire the diameter of which is between 2 and 5
20 percent greater than that of the outer wires. This larger size of the core wire is of importance in obtaining a strand which has good coherence and in

which the outer wires fit tightly against the core wire. Although this type of strand form is the most popular one used for prestressing, the invention is not restricted to this specific strand construction, but also relates to other strand constructions of the general type indicated in the first paragraph above.

Referring now to Figs. 1 and 2 of the accompanying drawings, these show a prestressing strand having a single core wire *b* and six outer wires *a* in longitudinal view and in cross section respectively. Fig. 1 also indicates the pitch of the helices in which each of the outer wires lies. For the whole strand, this pitch *S* is referred to herein by the expression "helical pitch length". Fig. 2 indicates the greatest cross sectional dimension which is herein called the maximum diameter of the strand. It is usual to express the helical pitch length as a multiple of the strand diameter. For prestressing strands, this length *S* generally lies between 12 and 18 times the diameter, although a value of *S* in this range is not essential for the present invention.

The present invention arises because, for prestressing strand, investigations do not appear to have resulted in the most suitable practical strand construction for use in prestressing.

In the tensioning of a prestressing strand, usually the elongation properties of the strand under tensioning in an unhindered straight condition are employed. In this it has been found that the ratio
5 between the mean stress over the cross section of the strand and its strain deviates little from the elasticity modulus E (Young's modulus) of the wire material. Small deviations can arise, in dependence on the production method of the strand and its construction.

10 In the use of prestressing strands in curved conduits through concrete structures, in different cases different tension forces appear at the strand ends after tensioning. By means of calculations it is possible to find a relationship between the total
15 elongation of the strand in the curved channel and these tension forces at the ends, from which it is then possible to learn about the behaviour of the tension forces in the strand along its length, by applying a predetermined elongation to the strand.

20 It has now been found that in such cases, as a consequence of variations in the frictional properties inside the strand, variations in the production methods of the cable and possibly other factors, great deviations can be found between the calculated
25 elongations and elongations actually occurring in the tensioning of prestressing strand. If the quotient

of the mean stress over the strand cross section and the measured elongation of the strand per unit length is referred to by the expression "modulus of deformation", then it is found that, when tensioning strand in curved
5 conduits, this deformation modulus as a rule deviates considerably and unpredictably from the modulus of elasticity E of the wire material. More specifically it is found that the modulus of deformation in cases of substantial variation is as a rule smaller than
10 the modulus of elasticity. This is the more serious, because in the application of a calculated elongation to the prestressing strand, an uncertainty exists whether along the whole length, the designed tension exists in the strand, and whether the concrete structure
15 arrives at the desired condition of prestress.

The tension condition and the deformation condition of a prestressing strand in a curved configuration, in which the strand is subjected to transverse forces and frictional forces, is highly complex, and
20 is dependent on a great number of factors which are related to the properties of the material and the production methods for the strand.

A complete understanding of this has not yet been achieved, though by an empirical method the
25 inventors of the present application can indicate systematic variations. The method of testing strands is described below.

SUMMARY OF THE INVENTION

The object of the present invention is therefore to make it possible to control and minimize variations in tension in prestressing strand in curved
5 conduits.

The inventors have realised that a considerably better consistency between the modulus of deformation and the modulus of elasticity can be obtained when the core wire can be more adequately tensioned over
10 its whole length and can cooperate better as a load bearing element. Also the prestressing strand must sufficiently remain integral in order that slip between the core wire and the outer wires is prevented, since this slip has the result that locally the core wire
15 is no longer fully under load.

It has been found that such improved prestressing strands of the above referred to type can be obtained if at least the or each core wire has a modified surface resulting in a reduced tendency
20 to movement (e.g. increased coefficient of friction) of the core and outer wires relative to each other.

The outer wires may also have a modified surface resulting in a reduced tendency to such movement. Thus the core wire, and optionally also the outer
25 wires, have been subjected to a treatment to modify the wire surface so that the resistance to relative

longitudinal movement of the core wire and the outer wire is greater than it would be if the treatment had not been performed.

One treatment method for the core, and optionally
5 the outer wires is to form mechanically indentations in the wire surface.

Another treatment method is to modify the surface condition of the wire so as to increase the coefficient of friction between the core wire and
10 the outer wires. Thus, instead of accepting undesired variations in the frictional properties inside the strand, use is made of these frictional properties, by increasing this friction in order to reduce or even prevent any movement in longitudinal direction
15 between the core wire and the outer wires.

Various alternative methods are available for modifying the surface condition of the core and outer wires in order to increase the coefficient of friction. One possibility is that the surface of
20 the wire is given a thin oxide layer resulting from heating the wire in an oxidising atmosphere. It will be clear that even a very thin oxide layer can drastically influence the frictional properties of the wires, without affecting the strength and durability of the
25 wire and of the prestressing strand as a whole. Anyone skilled in the art will know how for each type of core wire such a thin oxide layer can be achieved

by selection of oxidising atmosphere, process temperature and a period of treatment of the wires, without affecting the relevant physical properties of the wire material, such properties being for example (but not exclusively) the mechanical properties and the durability.

It has also been found that the surface condition of the wire can be adequately modified by subjecting it to a chemical etching treatment. Chemical etching treatments of steel products are generally known, which means that no further explanation needs to be given how such etching is to be performed in order to achieve a slight roughening of the surface, without unduly affecting the physical properties of the material.

Also, it has been found that the object of the present invention may be obtained, without modifying the wire itself, if a resin coating in which an abrasive powder, e.g. a grinding powder such as carborundum, is admixed is applied to the wire. In prestressing strand constructed with such a coated wire, the particles of the grinding powder prevent or at least reduce movement between the various wires.

Yet another possibility for the wire treatment consists in depositing a friction-increasing substance upon the wire by an electrochemical or an electrostatic process. In this field there are many

options available to the expert for achieving suitable deposition.

Although several different alternatives have been discussed for modifying the surface of the wire, combinations of two or more of such surface modification processes can be employed in the present invention.

The invention also relates to the process of manufacture of the prestressing strand and to a concrete structure containing one or more tensioned strands according to the invention, as described above. In such a manufacturing process, it is assumed that the manufacturing steps start from wire of surface condition hitherto conventional in this field, e.g. as supplied by wire manufacturers.

15 BRIEF INTRODUCTION OF THE DRAWINGS

Embodiments of the invention will be described below by way of non limitative example with reference to the accompanying drawings, in which:

Figs. 1 and 2 show a prestressing strand and have been described above;

Fig. 3 shows a test apparatus for prestressing strand in plan view;

Fig. 4 is a front view of the apparatus of Fig. 3;

25 DESCRIPTION OF THE DRAWINGS

Figs. 3 and 4 show a concrete plate 1 with

a thickness of 22 cm. Through this plate 1 there extends a conduit 3 which over an angle of 5.07 radians is curved with a radius of curvature R of 100 cm. The length L_2 of the curved conduit part is consequently 507 cm. Against each end of the conduit 3 there is located a support beam 2 with at the left hand side a wedge anchoring 5 for a prestressing strand and at the right hand side a similar wedge anchoring 5 behind a hydraulic press 4 (schematically shown).

After a strand is inserted through the conduit 3, the strand is secured by the wedge anchors 5, whereupon it is tensioned by the hydraulic press 4. The tensioned strand then consists of a straight section of length L_1 of 175 cm, a curved section of length L_2 of 507 cm and another straight section of length L_3 of 210 cm.

Tests were carried out using the most common prestressing strand of thickness D of 0.5 inches, and having a core wire and six outer wires. First the strand was brought under nominal tension, in order to stretch it sufficiently, whereupon the tension force was increased up to a value near the usual full load value used in tensioning technology. During the increase of the tension force, the elongation and the tension force in the strand were measured continuously.

Using the "element method", the strand was considered to be divided into elements, and for each element the stress and strain conditions were calculated with the application of a frictional force between the channel wall and the prestressing strand. By means of separate tests with small angles of wrap, frictional coefficients between the strand and the channel wall at various tension forces in the strand were determined. Per element, these friction coefficients were introduced into the calculation so that it was possible to determine by calculation, what tension forces should be present in the strand, on the basis of the total measured extension of the strand between the anchors 5. This value was compared with the actual tension forces obtained, from which a value could be obtained for the modulus of deformation in each test performed.

This test was repeated with strands having a modified core wire according to the invention, but otherwise of the same dimensions. In each case, in a corresponding manner, a value for the modulus of deformation was determined.

The values thus found by measurement and calculation for the modulus of deformation showed that in all cases with the use of modified core wires (and optionally modified outer wires) according to the invention a substantial increase of the modulus of deformation was found, while also the difference between the modulus of deformation and the modulus of elasticity became unimportant.

WHAT IS CLAIMED IS:

1. Prestressing strand for use in stressing a concrete structure, having at least one central core wire and a plurality of outer wires extending helically around the said core wire so as to envelop
5 the core wire, wherein at least the said core wire has been subjected to treatment to give it a modified surface such that as a result of said treatment the resistance to longitudinal movement of the core wire relative to the outer wires is greater than if said
10 treatment was not performed.
2. Prestressing strand according to claim 1 wherein the outer wires have also been subjected to treatment to give them modified surfaces such that
15 as a result of said treatment of the outer wires the resistance to longitudinal movement of the core wire relative to the outer wires is greater than if said treatment of the outer wires was not performed.
3. Prestressing strand according to one of claims 1 and 2 wherein said treatment of the core
20 wire and, if performed, said treatment of the outer wires, comprises mechanically forming indentations in the wire surface.

4. Prestressing strand according to one of
claims 1 and 2 wherein said treatment of the core
wire and, if performed, said treatment of the outer
wires comprises modifying the wire surface condition
5 so as to increase the coefficient of friction between
the core wire and the outer wires.
5. Prestressing strand according to claim 4
wherein said treatment is at least one of the following:
- a) creation of a thin oxide layer by heating
10 the wire in an oxidizing atmosphere;
 - b) chemical etching of the wire;
 - c) application to the wire of a resin coating
containing an abrasive powder;
 - d) deposition on the wire surface of a friction-
15 increasing substance.
6. A concrete structure containing at least
one tensioned prestressing strand according to claim
1.
7. A concrete structure according to claim
20 6, wherein the said tensioned strand extends along
a curved conduit within the concrete structure.

8. A process of manufacture of prestressing strand for use in stressing a concrete structure, comprising providing at least one central core wire and a plurality of outer wires and wrapping said outer
5 wires helically around the core wire so as to envelop the core wire, which method further comprises prior to said wrapping step, subjecting at least the core wire to treatment so as to give it a modified surface such that as a result of said treatment the resistance
10 to longitudinal movement of the core wire relative to the outer wires is greater than if said treatment was not performed.

9. A process according to claim 8 further comprising, prior to said wrapping step, subjecting
15 the said outer wires to treatment to give them modified surfaces such that as a result of said treatment of the outer wires the resistance to longitudinal movement of the core wire relative to the outer wires is greater than if said treatment of the outer wires
20 was not performed.

10. A process according to one of claim 8 and claim 9 wherein said treatment of the core wire and, if performed, said treatment of the outer wires, comprises mechanically forming indentations in the wire surface.

11. A process according to one of claim 8 and claim 9 wherein said treatment of the core wire and, if performed, said treatment of the outer wires comprises modifying the wire surface condition so
- 5 as to increase the coefficient of friction between the core wire and the outer wires.
12. A process according to claim 11, wherein said treatment to increase the coefficient of friction comprises at least one of the following steps:
- 10 a) forming a thin oxide layer by heating the wire in an oxidising atmosphere;
- b) chemically etching the wire surface;
- c) applying to the wire a resin coating containing an abrasive powder;
- 15 d) depositing on the wire surface a friction-increasing substance.

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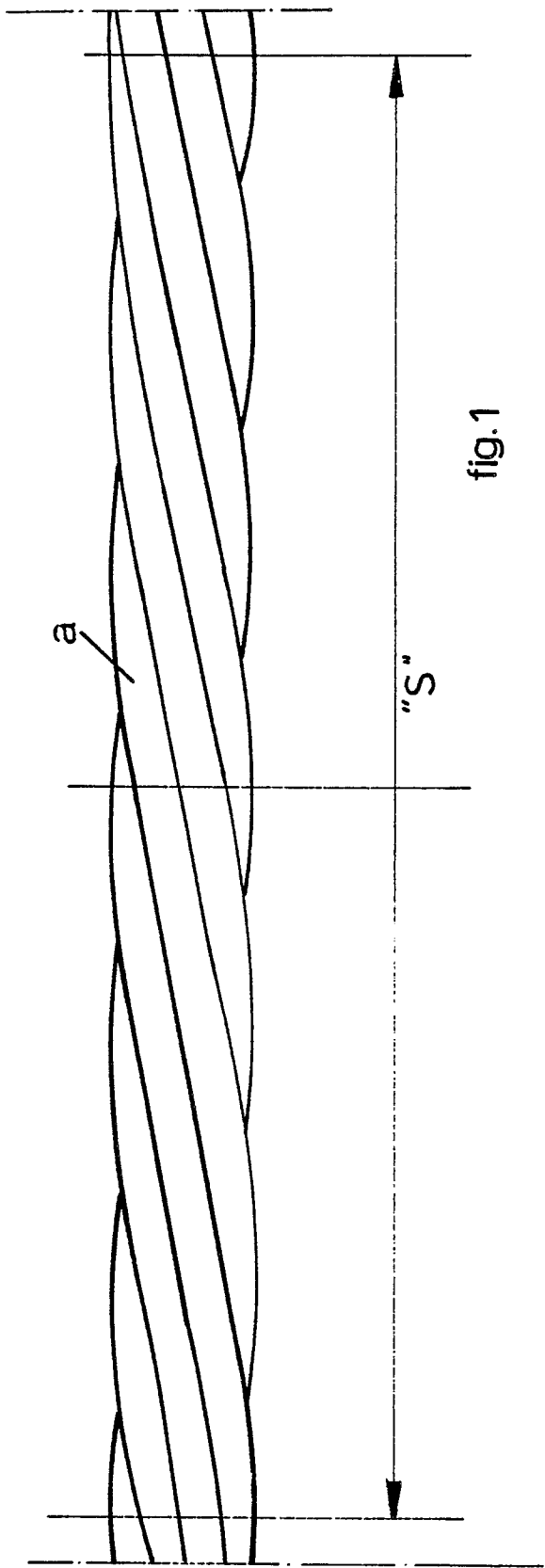


fig. 1

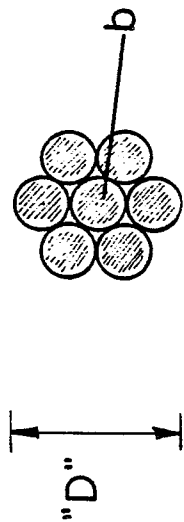


fig. 2

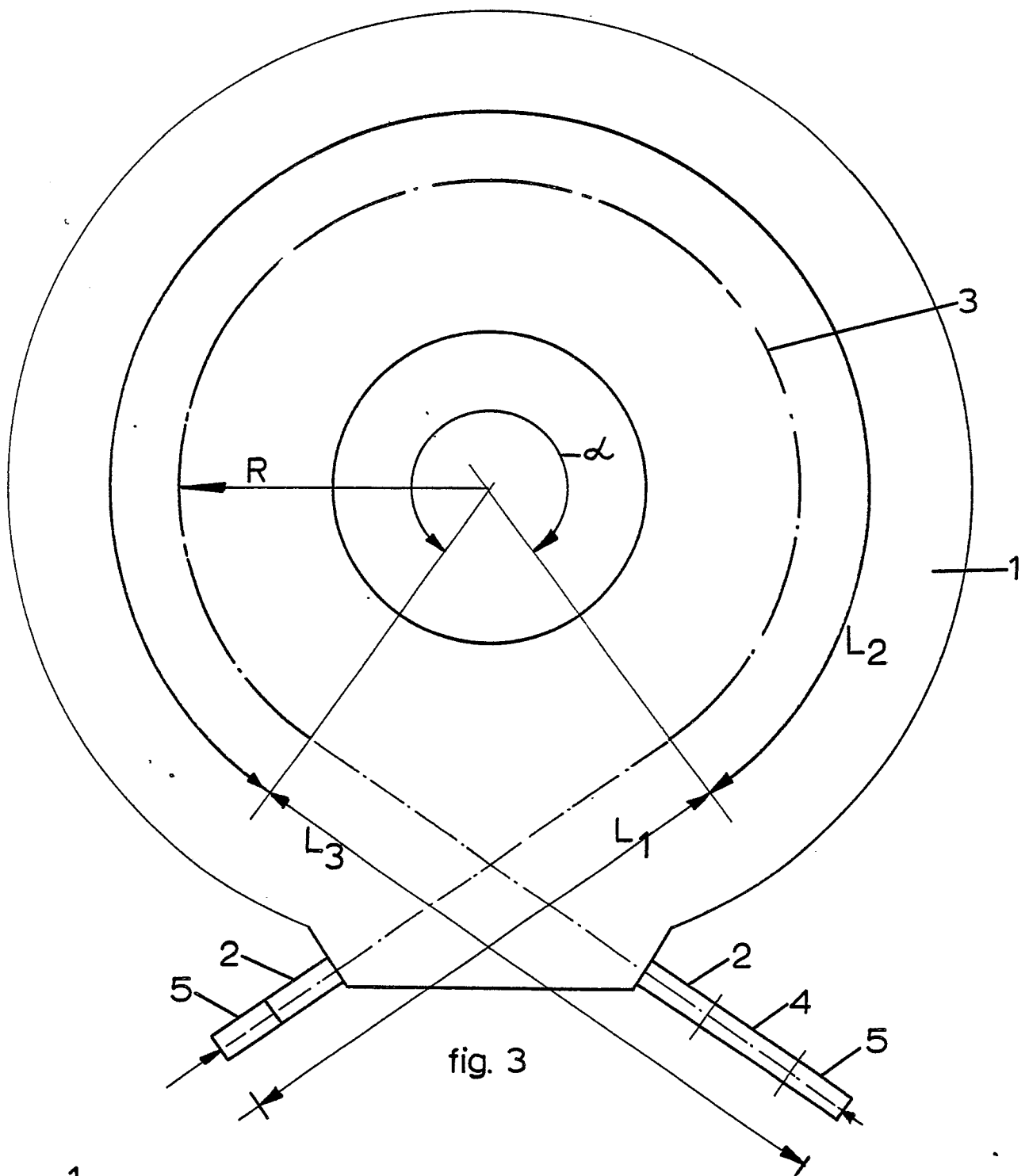


fig. 3

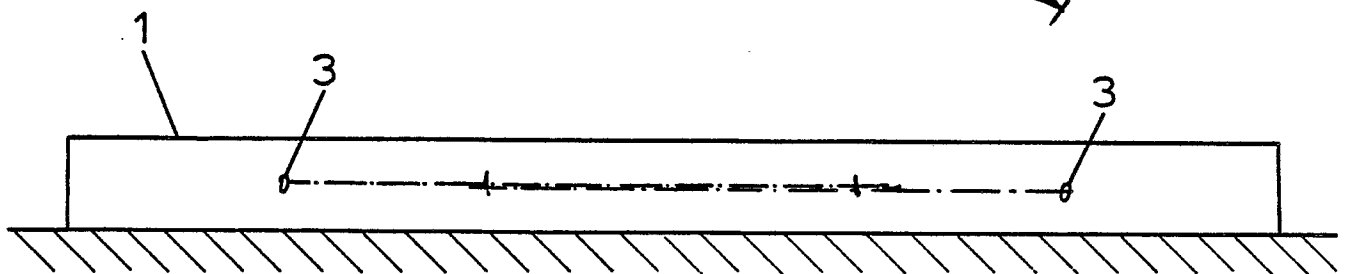


fig. 4