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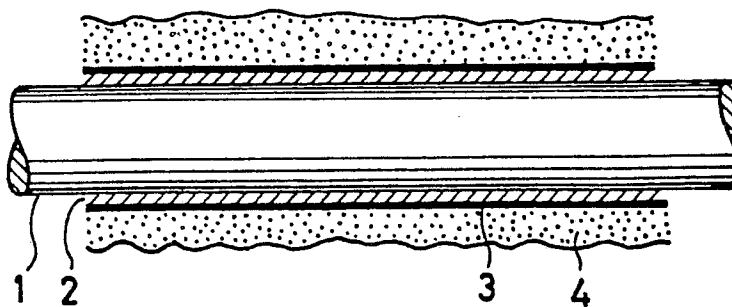
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54 **Prestressing steel material.**

57 A steel material for use with concrete that is prestressed by posttensioning is disclosed. The steel member is sheathed with a heat-shrinkable synthetic resin tube. Said embodiment is further applicable to the case of a stranded steel member.

FIG. 1



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PRESTRESSING STEEL MATERIAL

The present invention relates to steel materials for use with concrete that is prestressed by posttensioning.

Concrete has a relatively low tensile strength. In order to overcome this disadvantage, prestressed concrete has been developed. By means of high strength steel wires, bars or strands, a concrete member is precompressed. When the structure receives a load, the compression is relieved on that portion which would normally be in tension.

There are two general methods of prestressing, namely, pretensioning and posttensioning. The present invention relates to steel materials for use with concrete of the type that is prestressed by posttensioning.

Structural designs used to prevent direct contact between steel materials and the surrounding prestressed concrete are illustrated in Figs. 1 and 2. The design shown in Fig. 1 can be used whether the steel material is in the form of a wire, bar or strand. A steel member 1 having a grease coating 2 is sheathed with a PE (polyethylene) tube 3. When the steel member 1 with the PE tube 3 is placed within a concrete section 4, the lubricating effect of the intermediate grease coating 2 reduces the coefficient of friction between the steel member and concrete to as low as between 0.002 and 0.005 m^{-1} . Because of this low coefficient of friction, the design in Fig. 1 provides great ease in posttensioning a long steel cable in concrete. However, if the steel material is of short length, the need for preventing grease leakage from either end of the PE tube presents great difficulty in fabricating and handling the steel material. Furthermore, steel members having screws or heads at both ends are difficult to produce in a continuous fashion.

The steel member 1 shown in Fig. 2, which is encapsulated in asphalt 5, has a slightly greater coefficient of friction than the structure shown in Fig. 1. This design is extensively used with relatively short steel materials since it is simple in construction, is leak-free, and provides ease in unbonding the steel material from the concrete, even if the steel member has screws or heads at end portions.

One problem with the design in Fig. 2 is that the presence of the asphalt (or, alternatively, a paint) may adversely affect the working environment due to the inclusion therein of a volatile organic solvent. Moreover, the floor may be fouled by the splashing of the asphalt or paint. As another problem, great difficulty is involved in handling the coated steel material during drying or positioning within a framework, and separation of the asphalt coating can easily occur unless utmost care is taken in ensuring the desired coating thickness.

Accordingly, it is the object of the present invention to provide a steel material for use with prestressed concrete that is free from the problems associated with the prior art techniques.

This object of the present invention is achieved by sheathing a steel material for prestressed concrete with a heat-shrinkable synthetic resin tube.

Figs. 1 and 2 show schematically conventional designs of steel materials for concrete prestressed by posttensioning;

Fig. 3 is a schematic presentation of a steel material of the present invention for use with prestressed concrete; and

Fig. 4 shows a cross section of a steel strand sheathed with a resin tube according to the present invention.

Hereinafter, the present invention will be described in detail with references to Fig. 3 and 4, in which reference numeral indicates a steel member (1) and reference numeral 6 a heat-shrinkable synthetic resin tube.

The steel member is sheathed with a heat-shrinkable synthetic resin tube.

The steel material need not be bonded to the heat-shrinkable synthetic resin tube with an adhesive material. If improved rust-preventing and anti-corrosion effects are desired, the steel member and the resin tube may be bonded by an adhesive material. If the steel member is a bar, a heat-fusible synthetic resin adhesive is coated or placed on the inner surface of the resin tube or the outer surface of the steel bar, and, after the resin tube is slipped over the steel bar, heat is applied to cause the resin tube to shrink as the resin adhesive melts to provide firm adhesion between the steel bar and the resin tube. It has been found by the present inventors that this method is the simplest and best way to ensure firm bonding between the steel bar and the synthetic resin tube.

The steel material for prestressed concrete according to this embodiment is illustrated in Fig. 3, wherein reference numeral 1 refers to the steel member and 6 represents the heat-shrinkable synthetic resin tube coated on the surface of the steel member. In one preferred example, the steel member 1 is inserted into a prefabricated heat-shrinkable synthetic resin tube, which is then heated by hot air, steam or with an IR (infrared) heater to shrink and tightly fit it onto the surface of the steel member.

The wall thickness of the heat-shrinkable synthetic resin tube must be at least 300 μm (microns) to isolate the steel member 1 and the surrounding concrete layer sufficiently to provide good slippage between the two components. The wall thickness of the synthetic resin tube after heat shrinking can be approximated by the following equation:

$$t = (1/2)((D + 2t_1)^2 - D_1^2 + D_0^2)^{1/2} - D_0,$$

where t: wall thickness (mm) after heat shrinking

D_0 : outside diameter (mm) of steel bar

D_1 : inside diameter (mm) of the tube before heat shrinking

t_1 : wall thickness (mm) before heat shrinking.

If a steel bar of $D_0 = 17$ mm is inserted into a resin tube having an inside diameter of 20 mm and a wall thickness of 0.3 mm and if the tube is heat-shrunk to provide intimate contact with the steel bar, the tube around the steel bar will have a wall thickness as large as about 0.35 mm. A heat-shrinkable polyolefin tube has a heat shrinkage of about 35%. Thus, the inside diameter of the tube can be selected from the range of 1.1 to 1.5 times the outside diameter of the steel bar. This fairly large inside diameter of the polyolefin tube permits considerable ease in inserting the steel bar through the tube. Furthermore, by properly selecting the inside diameter and wall thickness of the heat-shrinkable synthetic resin tube to be used with a steel bar having a specific outside diameter, the desired wall thickness of the tube will be provided around the steel bar after heat shrinkage.

Samples of steel materials for use with prestressed concrete that included steel members coated with a heat-shrinkable synthetic resin tube were fabricated and subjected to various tests to determine their properties. The results are shown in Tables 1 to 3.

Table 1

	Basic properties of Samples
Dimensions of steel member:	Bar having an outside diameter of 17 mm and a length of 2,830 mm
Resin tube:	High-density polyethylene tube that was rendered heat-shrinkable by cross-linking under exposure to electron beam
Density:	0.95 g/cm ²
Tensile strength:	1.0 kg/mm ²
Elongation:	300%
Heat resistance:	350 ° C (1 min.)
Saltwater resistance:	OK
Alkali resistance:	OK
Acid resistance:	(10% HCl) OK
	(10% H ₂ SO ₄) OK

Table 2

Sample No.	Load (Kgf)		Frictional loss (Kgf)	Frictional coefficient λ (m^{-1})	Remarks
	Tensioned side (Pi)	Fixed Side (Po)			
1	19.490	19.110	380	0.00817	Length of concrete section: $l = 2,435$ mm
2	19.540	19.135	405	0.00869	
3	19.530	19.190	340	0.00728	
4	19.480	19.105	375	0.00806	Sample temperature: $T = 25^{\circ}C$
5	19.510	19.015	495	0.01069	
6	19.500	19.185	315	0.00674	
7	19.520	19.065	455	0.00980	Frictional coefficient: $\lambda = \left(\frac{P_o}{P_i} - 1 \right) \cdot \frac{1}{l}$
8	19.500	18.970	530	0.01147	
9	19.510	19.080	430	0.00926	
10	19.470	19.110	360	0.00774	

Table 3

Test	Conditions	Results
1. Continuous saltwater spray test (2,000 hrs)	JIS Z 2371 (5% aq. NaCl, $35^{\circ}C$)	No rust or blister formed on the sample surface
2. Saltwater immersion test (2,000 hrs)	Immersed in 3% aq. NaCl at $25^{\circ}C$	No rust on the intern steel bar. No rust or blister formed on the sample surface. No rust on the intern steel bar.
3. Alkali resistance test (2,000 hrs)	Immersed in 3% aq. NaCl at $25^{\circ}C$ that was adjusted to pH 11 with KOH	No rust or blister formed on the sample surfact. No rust on the intern steel bar.

The present invention is also applicable to a steel strand composed of a plurality of twisted steel wires as shown in Fig. 4. The resulting strand has spiral grooves as indicated by A and B in Fig. 4. Not only do these grooves render the posttensioning of the strand difficult, but they also increase the frictional resistance on the stressed concrete. In order to avoid these problems, the grooves are filled with a resin. Such filling with a resin may be accomplished by extrusion or other suitable techniques. Subsequently, the thus-treated steel strand is sheathed with the foamed synthetic resin tube as above.

According to the present invention, a steel material for use with prestressed concrete can be easily manufactured. The resulting steel material is easy to handle during transportation and installation.

Claims

1. An elongated prestressing steel material embedded in prestressed concrete (4), wherein said prestressing steel material comprises a steel member (1) and a heat-shrinkable synthetic resin tube (6) surrounding the outer surfaces of said steel member (1), and in which the prestressing steel material is subjected to posttensioning in an unbounded state wherein the prestressing steel material is not bonded to and is free to move relative to the concrete (4), and wherein the steel member is bonded to and is not movable relative to the heat-shrinkable synthetic resin tube (6).
2. A prestressing steel material embedded in prestressed concrete (4), wherein said prestressing steel material comprises a steel strand comprising a plurality of steel wires twisted together, said steel strand having spiral grooves (A, B), a resin filling said grooves; and a heat-shrinkable synthetic resin tube (6) covering said strand and said resin and heat-shrunk around said strand to provide intimate contact between said strand and said resin tube and further comprising an adhesive material provided between the steel member and the heat-shrinkable synthetic resin tube, wherein upon application of heat, the tube shrinks as the adhesive melts to adhere the steel member and the resin tube and wherein the prestressing steel material is free to move relative to the concrete and the steel strand is not movable relative to the heat-shrinkable synthetic resin tube.
3. An elongated prestressing steel material embedded in prestressed concrete, wherein said prestressing steel material comprises a steel member, a heat-shrinkable synthetic resin tube surrounding the outer surfaces of said steel member, and an adhesive material provided between the steel member and the heat-shrinkable synthetic resin tube, wherein upon application of heat, the tube shrinks as the adhesive melts to adhere the steel member and the resin tube and wherein the prestressing steel material is in an unbonded state and is free to move with respect to the concrete and the steel member is not movable relative to the heat-shrinkable synthetic resin tube.
4. The steel material of any of claims 1 to 3, wherein a wall thickness of said resin tube is at least 300 μm .
5. The steel material of any of claims 1 to 3, wherein said resin material is a polyolefin.
6. The steel material of any of claims 1 to 3, wherein said resin is a high-density polyethylene..

FIG. 1

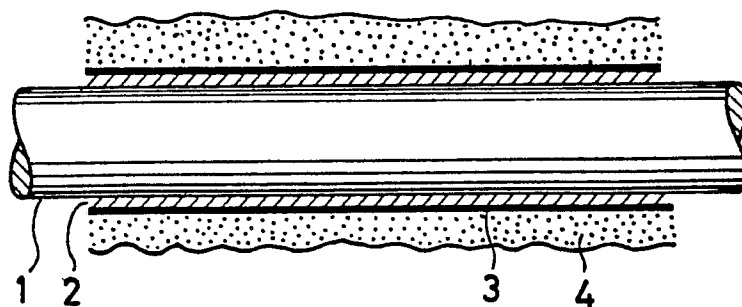


FIG. 2

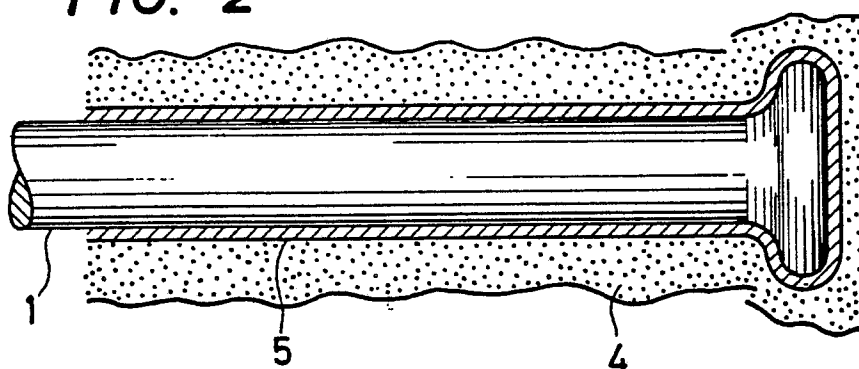


FIG. 3

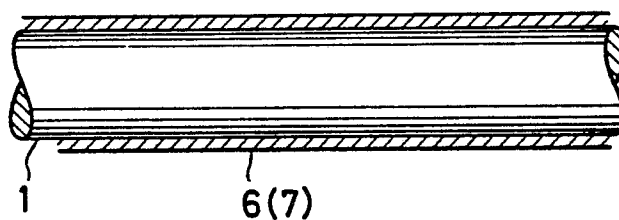


FIG. 4

