

①②

EUROPEAN PATENT APPLICATION

②① Application number: **84115412.3**

⑤① Int. Cl.⁴: **E 04 C 5/08, D 07 B 1/16**

②② Date of filing: **14.12.84**

③① Priority: **16.12.83 JP 194473/83 U**
16.12.83 JP 194474/83 U

⑦① Applicant: **SUMITOMO ELECTRIC INDUSTRIES LIMITED, No. 15, Kitahama 5-chome Higashi-ku, Osaka-shi Osaka-fu (JP)**

④③ Date of publication of application: **26.06.85**
Bulletin 85/26

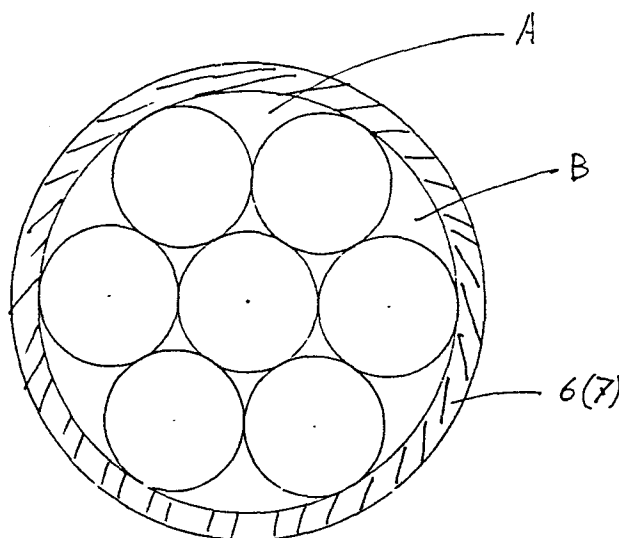
⑦② Inventor: **Watanabe, Kanji c/o Itami Works of Sumitomo, Electric Industries Ltd No.1-1 Koyakita 1-chome, Itami-shi Osaka (JP)**
Inventor: **Mizoe, Mikio c/o Itami Works of Sumitomo, Electric Industries Ltd No.1-1 Koyakita 1-chome, Itami-shi Osaka (JP)**
Inventor: **Inoo, Eiichi c/o Itami Works of Sumitomo, Electric Industries Ltd No.1-1 Koyakita 1-chome, Itami-shi Osaka (JP)**

⑥④ Designated Contracting States: **DE FR GB IT**

⑦④ Representative: **Patentanwälte Grünecker, Dr. Kinkeldey, Dr. Stockmair, Dr. Schumann, Jakob, Dr. Bezold, Meister, Hilgers, Dr. Meyer-Plath, Maximilianstrasse 58, D-8000 München 22 (DE)**

⑤④ **Steel materials for use with prestressed concrete.**

⑤⑦ Steel materials for use with concrete that is prestressed by posttensioning are disclosed. In accordance with one embodiment of the invention, a steel member is sheathed with a heat-shrinkable synthetic resin tube. In another embodiment, the steel member is sheathed with a foamed synthetic resin tube. Both embodiments are further applicable to the case of a stranded steel member, in which case it is preferred that the spiral grooves of the stranded member be filled with a resin before sheathing with an external tube.



STEEL MATERIALS FOR USE WITH PRESTRESSED CONCRETE

BACKGROUND OF THE INVENTION

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 3, 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

- 3 -

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.

SUMMARY OF THE INVENTION

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

These and other objects of the present invention are achieved by sheathing a steel material for prestressed concrete with a heat-shrinkable synthetic resin tube or a foamed synthetic resin tube.

BRIEF DESCRIPTION OF THE DRAWINGS

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.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, the present invention will be described in detail with reference to Figs. 3 and 4, in which reference numeral indicates a steel member (1) and reference numeral 6 (7) a heat-shrinkable synthetic resin tube (foamed synthetic resin tube).

Embodiment 1

According to this embodiment, 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 the 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 microns in order to isolate the steel member 1 and the surrounding concrete layer sufficiently to provide good slippage between the two components. The wall thickness to of the synthetic resin tube after heat shrinking can be approximated by the following equation:

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

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 1Basic 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 2Unbonding (Frictional) Properties

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: $\ell = 2,435$ 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	
5	19.510	19.015	495	0.01069	Sample tempera- ture: T=25°C
6	19.500	19.185	315	0.00674	
7	19.520	19.065	455	0.00980	
8	19.500	18.970	530	0.01147	Frictional coeffi- cient: $\lambda = \left(\frac{P_i}{P_o} - 1\right) \cdot \frac{1}{\ell}$
9	19.510	19.080	430	0.00926	
10	19.470	19.110	360	0.00774	

Table 3

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

Embodiment 2

According to this embodiment, the steel member is sheathed by a foamed synthetic resin tube 7 in Fig. 3. Various methods may be used to cover the steel member 1 with the resin tube. In one method, a synthetic resin powder containing a blowing agent is applied to provide a foamed coating on the surface of a preheated steel member by a fluidized dip coating or electrostatic coating technique. Alternatively, a film of synthetic resin containing a blowing agent is formed on the surface of the steel member 1, which is then passed through a heating chamber to expand the resin film into a foam. If desired, a preliminarily formed synthetic resin foam tube 6 may be slipped over the steel member 1. The resin tube 6 may or may not be bonded to the steel member 1.

In order to isolate the steel material 1 sufficiently from concrete to facilitate the subsequent posttensioning, the foamed synthetic resin tube 6 must have a wall thickness of at least 300 microns. Furthermore, in order to reduce the frictional resistance and therefore the slippage between the steel member 1 and the concrete, the resin tube 6 preferably has a wall thickness of at least 500 microns.

Steel bars, one example of a steel member

- 11 -

according to the present invention, were sheathed with a foamed polyethylene tube. The tube was prepared from a blowing agent loaded polyethylene powder that was applied to preheated steel bars using a fluidized dip coating technique. The properties of these samples were as shown in Tables 4 and 5:

Table 4Basic Properties of Steel Bars

Bar dimensions:	17 mm ϕ X 2,830 mmL
Polyethylene tube:	prepared from medium-density PE powder (density: 0.925 g/cm ³ , m.p. 120°C) containing 1.0% heat-decomposable blowing agent
Wall thickness of polyethylene tube:	1.3 - 1.5 mm
Occluded cells:	Open cells of a size of 0.3 - 0.5 mm distributed uniformity in a thickness of 3 - 4 microns

Table 5Unbonding (Frictional) Properties

Sample No.	Load (Kgf)		Frictional loss (Kgf)	Frictional coefficient λ (m ⁻¹)	Remarks
	Tensioned side (Pi)	Fixed Side (Po)			
1	19.510	19.140	370	0.0079	Length of concrete section: $l=2,435$ mm
2	19.540	19.200	340	0.0073	
3	19.500	19.010	490	0.0106	
4	19.480	19.040	440	0.0095	Sample tempera- ture: T=25°C
5	19.510	19.115	395	0.0085	
6	19.530	19.170	360	0.0077	
7	19.500	19.040	455	0.0098	Frictional coeffi- cient: $\lambda = \left(\frac{P_i}{P_o} - 1 \right) \cdot \frac{1}{l}$
8	19.510	18.965	545	0.0118	
9	19.500	19.220	280	0.0060	
10	19.490	19.125	365	0.0078	

Table 6

<u>Sample</u>	<u>Resin coat Thickness (microns).</u>	<u>Surface features</u>	<u>Result</u>
Barax (unbonded)	300 - 500	unscratched	No rust formed even after 2,000 hrs
Barax (unbonded)	300 - 500	scratched	Severe rust formed around scratches after 200 hrs
Foamed polyethylene coating	300 - 500	unscratched	No rust formed even after 2,000 hrs
Foamed polyethylene coating	300 - 500	scratched	Rust formed only at scratches after 500 hrs

- 15 -

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 steel 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. A steel material for use with prestressed concrete, comprising: a steel member, and a foamed synthetic resin tube sheathing said steel member.

2. The steel material of claim 1, wherein a wall thickness of said tube is at least 300 microns.

3. The steel material of claim 1, wherein a wall thickness at least 500 microns.

4. The steel material of claim 1, wherein said synthetic resin is a foamed polyethylene tube.

5. The steel material of claim 1, wherein said synthetic resin tube is formed by applying a synthetic resin powder containing a blowing agent to a surface of said steel member preheated.

6. The steel material of claim 1, wherein said synthetic resin tube is formed by applying a film of synthetic resin containing a blowing agent to a surface of said steel member and then heating said steel member to expand said resin into a foam.

7. A steel material for use with prestressed concrete, comprising: a steel strand comprising a plurality of twisted steel wires, said steel strand having a plurality of spiral grooves foamed therein; a resin filling said grooves; and a foamed synthetic resin tube

sheathing said strand and said resin filling said grooves.

8. A steel material for use with prestressed concrete, comprising: a steel member, and a synthetic resin tube surrounding outer surfaces of said steel member.

9. The steel material of claim 1, wherein said synthetic resin tube is made of a heat-shrinkable resin.

10. The steel material of claim 2, wherein a wall thickness of said resin tube is at least 300 microns.

11. The steel material of claim 3, wherein said resin material is a polyolefin.

12. The steel material of claim 3, wherein said resin is a high-density polyethylene.

13. A steel material for use with prestressed concrete, comprising: a steel strand comprising a plurality of steel wires twisted together, said steel strand having spiral grooves; a resin filling said grooves; and a heat-shrinkable synthetic resin tube covering said strand and said resin and heat-shrunk around said strand to provide intimate contact between said strand and said resin tube.

1/2

FIG. 1

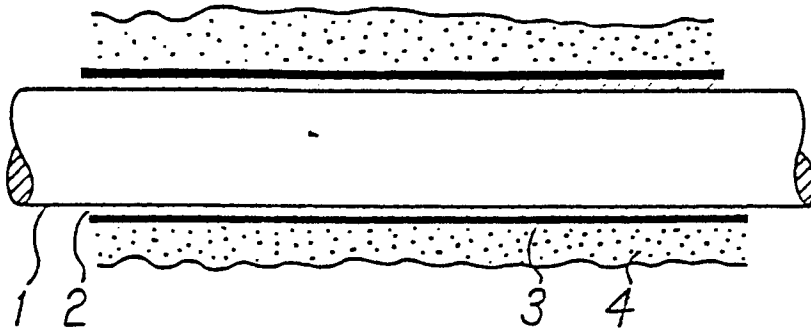


FIG. 2

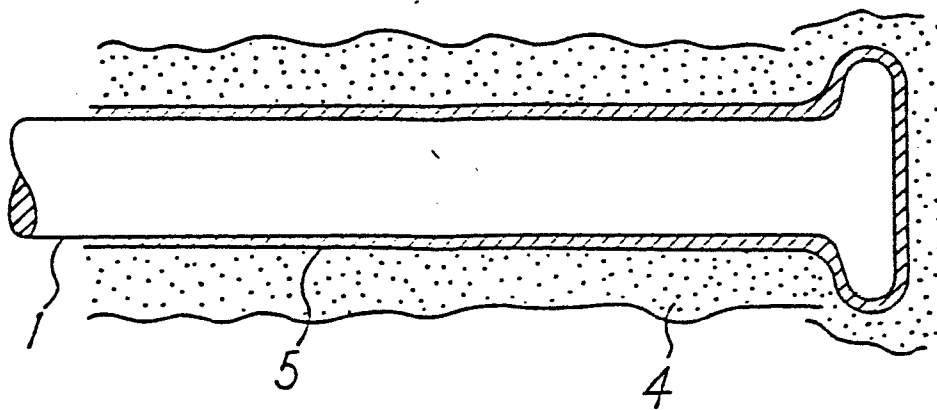


FIG. 3

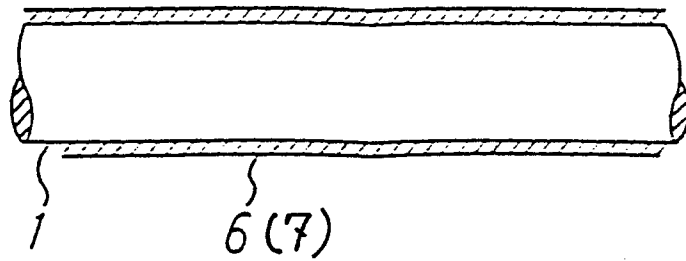


Fig. 4.

 $\frac{2}{2}$ 