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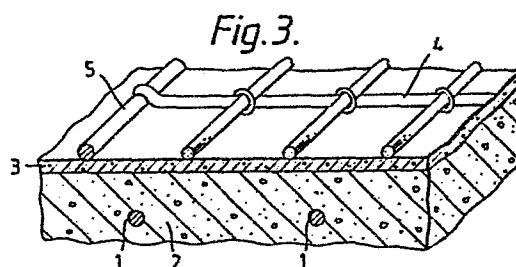
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54 Novel anodes for cathodic protection.

57 Novel anodes for cathodic protection systems comprise a plurality of elongate strands which are joined together to form an open flexible mesh. At least some of the strands are electrically conductive and comprise carbonaceous material which provides at least part of the electrochemically active surface of the anode. For example, the strands can consist of or contain carbon fibers and/or conductive polymer elements. The novel anodes are particularly useful for the cathodic protection of reinforcing bars in concrete structures.



FIELD OF THE INVENTIONBackground of the Invention

This invention relates to the cathodic protection of corro-dible substrates, in particular reinforcing bars in concrete.

Introduction to the Invention

Cathodic protection of metal substrates is well known. The substrate is made the cathode in a circuit which includes a DC current source, an anode, and an electrolyte between the anode and the cathode. The exposed surface of the anode is made of a material which is resistant to corrosion, for example platinum or a dispersion in an organic polymer of carbon black or graphite. The anode can be a discrete anode, or it can be a distributed anode in the form of an elongate strip or a conductive paint. There are many types of substrate which need protection from corrosion, including reinforcing members in concrete, which are often referred to as "rebar". Most Portland Cement concrete is sufficiently porous to allow passage of aqueous electrolyte through it. Consequently metal salt solutions which remain in the concrete or which permeate the concrete from the outside, will cause corrosion of rebar in the concrete. This is espe-

cially true when the electrolyte contains chloride ions, as for example in structures which are contacted by the sea, and also in bridges, parking garages, etc. which are exposed to water containing salt used for deicing procedures. The corrosion products of the rebar occupy a much larger volume than the metal consumed by the corrosion. As a result, the corrosion process not only weakens the rebar, but also, and more importantly, causes cracks and spalls in the concrete. It is only within the last ten or fifteen years that it has been appreciated that corrosion of rebar in concrete poses problems of the most serious kind, in terms not only of cost but also of human safety. There are already many reinforced concrete structures which are unsafe or unuseable because of deterioration of the concrete as a result of corrosion of the rebar, and unless some practical solution to the problem can be found, the number of such structures will increase dramatically over the next decade. Consequently, much effort and expense have been devoted to the development of methods for cathodic protection of rebar in concrete. However, the known methods yield poor results and/or involve expensive and inconvenient installation procedures.

For details of known methods of cathodic protection, reference may be made for example to U.S. Patents Nos. 4,319,854 (Marzocchi), 4,255,241 (Kroon), 4,267,029 (Massarsky), 3,868,313

(Gay), 3,798,142 (Evans), 3,391,072 (Pearson), 3,354,063 (Shutt), 3,022,242 (Anderson), 2,053,314 (Brown) and 1,842,541 (Cumberland), U.K. Patents No. 1,394,292 and 2,046,789A, and Japanese Patents Nos. 35293/1973 and 48948/1978, as well as copending commonly assigned Application Serial Nos. 403,203 (MP0769) and 485,572 (MP0861). The entire disclosures of each of the patents and applications listed above are incorporated herein by reference.

SUMMARY OF THE INVENTION

I have now discovered that excellent cathodic protection, coupled with ease of installation, can be obtained through use of a novel anode which comprises a plurality of elongate strands which are joined to each other to form a flexible open mesh, at least some of the strands being electrically conductive and comprising carbonaceous material which provides at least part of the electrochemically active surface of the anode. The novel anode is particularly useful for the cathodic protection of reinforcing members in concrete.

Brief Description of the Drawing

The invention is illustrated in the accompanying drawing, in which

Figures 1 to 4 are diagrammatic perspective views, partly in cross-section, of successive stages in the installation of an anode of the invention on a reinforced concrete structure;

Figure 5 is a diagrammatic perspective view, partly in cross-section of an anode of the invention installed on a reinforced concrete structure;

Figures 6 and 7 are diagrammatic perspective views, partly in cross-section, of alternative elongate strands for use in the anodes of the invention;

Figure 8 is a diagrammatic perspective view of an alternative anode of the invention;

Figure 9 is a diagrammatic perspective view of the installation of an anode of the invention

on a vertical surface of a reinforced concrete structure; and

Figure 10 is a diagrammatic perspective view of a panel containing an anode of the invention.

DETAILED DESCRIPTION OF THE INVENTION

In the novel anodes, at least some of the elongate strands are electrically conductive and comprise carbonaceous material which provides at least part of the electrochemically active surface of the mesh. Preferably the carbonaceous material provides all the electrochemically active surface of the mesh. However, the mesh can include other materials at its electrochemically active surface, or can be installed so that it is in physical and electrical contact with an electronically conductive material, eg coke breeze, which thus provides part of the electrochemically active surface of the anode. Such other materials can be resistant to corrosion or can be electrochemically sacrificial, provided that the electrochemical reaction products of such sacrificial materials do not produce any unacceptable results. In one preferred class, the conductive strands comprise carbonaceous fibers, particularly carbon fiber yarns, this term being used to include graphite fiber yarns. Such yarns are com-

mercially available, for example from Union Carbide, Hercules and Courtaulds. In another preferred class, the conductive strands comprise a continuous elongate metal core, and an elongate element which electrically surrounds the core and is in electrical contact therewith, and which is composed of an organic polymer and carbonaceous material (eg. carbon black or graphite) which is dispersed in the polymer. Such a strand can also comprise carbonaceous fibers, eg carbon or graphite fibers, which are partially embedded in the polymer and extend from its surface. For further details of such strands, reference should be made to Serial Nos. 403,203 and 485,572 incorporated herein by reference.

The physical and electrical characteristics of the elongate strands should be selected by reference to the intended use of the anode. If the strands do not have sufficient current-carrying ability to provide the desired current density at all points when connected to the power supply at a single point, then connection can be made at a plurality of points, or a bus bar, eg. a platinum or platinum-coated wire, can be connected to the conductive strands along one or more lines, eg. edges, of the mesh.

The mesh can consist substantially of elongate electrically conductive strands (some, and preferably all, of such strands having carbonaceous material at their electrochemically active

surface), or it can also contain non-conductive strands which help to provide the anode with its open mesh structure, for example glass fiber or organic polymer filament yarns. When non-conductive strands are present, they can all run in one direction, or some can run in one direction and others in a different direction; similarly the conductive strands can all run in one direction, or some can run in one direction and others in another direction.

The elongate strands can be joined together directly or indirectly in any convenient way, for example by knotting or melt-bonding, or with the aid of adhesive or clips. There can be electrical as well as physical connection at junctions between electrically conductive strands. The preferred size of the mesh depends somewhat upon the installation, bearing in mind both the electrochemical and physical requirements, including in some cases the relative coefficients of thermal expansion of the strands and the materials contacting them. When the anode is used to provide cathodic protection of the reinforcement in a concrete structure and is incorporated in the structure itself (as further described below), it is of course important that the apertures of the mesh should be sufficiently large to ensure that the structural components can bond to each other through the mesh, thus avoiding the possibility that the anode will create a

plane of weakness in the structure. The minimum dimension of the aperture (i.e. the length of the shortest side of the aperture) will generally be at least 0.5 inch (1.3 cm), preferably at least 1 inch (2.5 cm), particularly at least 2 inch (5.0 cm). The maximum dimension of the aperture (i.e. the length of the longest side of the aperture) will generally be less than 24 inch (60 cm), preferably less than 8 inch (20 cm) and in some cases less than 4 inch (10 cm) or less than 3 inch (7.5 cm). The apertures in the mesh can be of any shape, eg square or other rectangular shape, or diamond-shaped. The size and shape of the apertures are usually the same throughout a particular anode, but can be different.

The anodes of the invention are preferably flexible, this term being used herein to mean that the anode can be bent, along at least one axis, and preferably along two perpendicular axes, through an angle of 180° around a round mandrel of diameter 12 inch (30 cm), and preferably around a round mandrel of diameter 6 inch (15 cm), without suffering damage. This property results in a very significant advantage, namely that the anode can easily be transported in rolls to an installation site, and can be installed in a wide variety of different situations with a minimum of difficulty. In order to provide such flexibility, at least the strands running in one direction should be flexible.

In most cases, preferably all of the strands are flexible; however, the strands running in one direction can be relatively rigid, and the structural stability of the anode in that direction can make the product easier to handle and install in some situations.

The novel anodes are useful in any situation in which there is a requirement for corrosion protection over an area, especially in situations where low current densities are necessary or desirable. For example, the anode can be buried in the earth underneath a metal storage tank. However, the invention is particularly useful for the cathodic protection of rebar in concrete, and will be described in detail below by reference to such use.

In using the novel anodes for the cathodic protection of rebar in concrete, the anode is secured directly or indirectly to a surface of the concrete, preferably a surface which is parallel to the plane containing the rebar. The surface can be flat or curved or otherwise shaped, and it can be substantially horizontal or inclined to the horizontal (including vertical). There is no need, as in previously proposed processes, to cut slots in the concrete to accommodate the anode, which can lie adjacent the surface of the concrete, conforming to any irregularities of the surface.

In order to reduce the danger that the concrete will be damaged by excessive concentrations of the products of electrochemical reaction at the anode, the mesh anode and the concrete are preferably both contacted by a conductive material, especially one which is at least as conductive as the concrete. This material preferably helps to secure the anode to the concrete, and can provide some other useful, e.g. structural, function. If the material is electronically conductive, its effect is to increase the surface area of the anode. If the material is ionically conductive, electrochemical reaction will take place at the interface between it and the mesh anode. In either case, there will be a reduction in the concentration of harmful reaction products to which the concrete is exposed. The material is preferably one obtained by applying a shapeable (e.g. liquid or molten) composition and then causing or permitting the composition to solidify. In one embodiment, a layer of such material is formed on the concrete before the anode is put in place, and the anode then secured to the layer in electrical contact therewith, preferably through the use of the same or a different conductive material. Alternatively the anode is put in place, and the material is then applied to the anode and the concrete; the anode can be in direct contact with the concrete, or separated from the concrete, e.g. with the aid of insulating spacers, prior to application of the material. The material can

be for example based on Portland Cement concrete, asphalt concrete, plaster or an organic polymer, with, if required, a sufficient amount of an additive to achieve the desired electronic or ionic conductivity. The material should be selected having regard to the surface being treated; for example different compositions may be preferred for a horizontal surface and for a vertical column. The material can be applied in any convenient way; for example a conductive cement or mortar can be sprayed onto the concrete surface to which the anode is attached.

The novel anodes can also be used to prepare pre-cast panels for incorporation into structures. The anode can be incorporated in any relatively conductive material, eg. one of the materials used to secure an anode to a concrete surface as described above.

Referring now to the drawing, Figures 1 to 4 show successive stages in rendering a reinforced concrete structure suitable for cathodic protection. A mass of concrete 2 contains reinforcing bars 1. A layer of a more conductive concrete 3 is laid on top of the concrete 1. An anode comprising a mesh of carbon fiber yarns 4, tied together at the cross-over points, is placed on top of layer 3; a platinum-coated bus wire 5 makes contact with the yarns 4 running in one direction. A further layer 6 of conductive concrete, eg. asphalt concrete containing a conductive filler, is laid on top of the anode.

Figure 5 shows an anode which comprises a mesh of carbon fiber yarns 4 and which has been placed on the upper surface of a mass of concrete 2 containing reinforcing bars 1. The anode has been secured to the concrete by means of conductive grout 6 along the lines of the mesh.

Figure 6 shows a conductive strand comprising a metal, eg. copper, core 41 surrounded by a conductive polymer layer 42. Figure 7 is similar to figure 6, but also shows graphite fibers 43 partially embedded in the conductive polymer layer 42 and extending from the surface of the layer.

Figure 8 shows an anode in which the conductive strands 4 are joined together by insulating clips 44.

Figure 9 shows a concrete structure 2 which contains reinforcing rods 1 and around which is being wrapped a mesh anode 4.

Figure 10 shows a preformed panel in which an anode 4 and bus wire 5 are embedded within a layer 8 of conductive material. The panel also includes an inner layer 9 of a conductive adhesive for securing the panel to a substrate, and a layer 7 which may be a structural element or simply a protective covering, and which may be electrically conductive or non-conductive. The panel can also

include a further layer (not illustrated) which is bonded to the layer 7 and is a traffic-wearing layer.

CLAIMS

1. An anode suitable for use in the cathodic protection of corrodible substrates, characterized by comprising a plurality of elongate strands which are joined to each other to form a flexible open mesh, at least some of the strands being electrically conductive and comprising carbonaceous material which provides at least part of the electrochemically active surface of the mesh.

2. An anode according to Claim 1 characterized in that each of the electrically conductive strands is flexible and consists essentially of carbonaceous fibers.

3. An anode according to Claim 1 characterized in that each of the electrically conductive strands is flexible and comprises

- (a) a continuous elongate metal core, and
- (b) an elongate element which electrically surrounds the core, which is in electrical contact with the core, and which is composed of an organic polymer and carbonaceous material which is dispersed in the polymer.

4. An anode according to any one of Claims 1 to 3, characterized in that the minimum dimension of the apertures is at least 1 inch (2.5 cm), preferably at least 2 inch (5.1 cm).

5. An anode according to any one of Claims to 4, characterized in that the maximum dimension of the apertures is at most 4 inch (10.2 cm), preferably at most 8 inch (20.3 cm).

6. A method of cathodically protecting a corrodible substrate by establishing a potential difference between the substrate as cathode and an anode, characterized in that the anode is an anode as claimed in any one of Claims 1 to 5.

7. A method according to Claim 6 characterized in that the substrate comprises metal reinforcing bars encased in a mass of concrete, and the anode is secured to a surface of the mass of concrete with the aid of an ionically conductive material which is at least as conductive as the concrete.

8. A method according to Claim 7 characterized in that said material is based on Portland Cement concrete, asphalt concrete, plaster, or a polymer.

9. A method according to Claim 7 or 8 characterized in that the anode is secured to a substantially horizontal upper surface of the mass of concrete.

10. A method according to Claim 7 or 8, characterized in that the anode is secured to a substantially horizontal lower surface of the mass of concrete or to a surface of the mass of concrete which is substantially inclined to the horizontal.

Fig. 1.

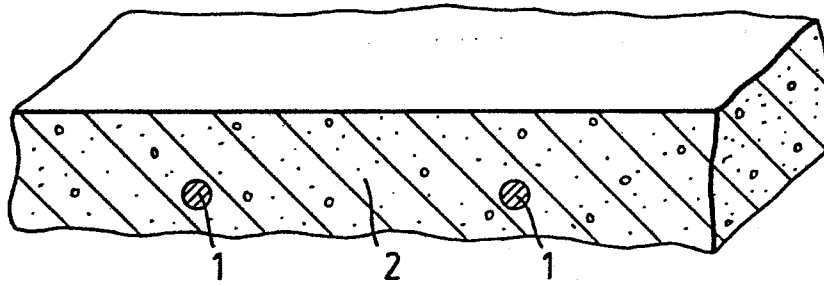


Fig. 2.

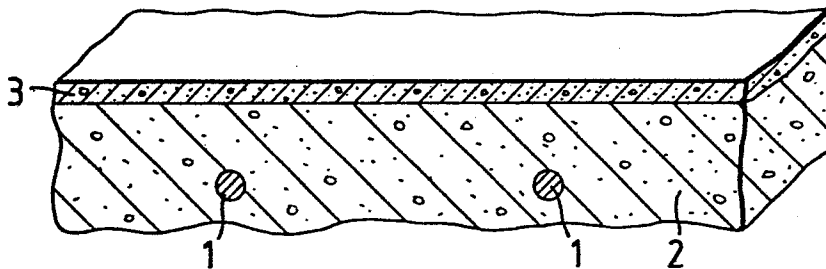


Fig. 3.

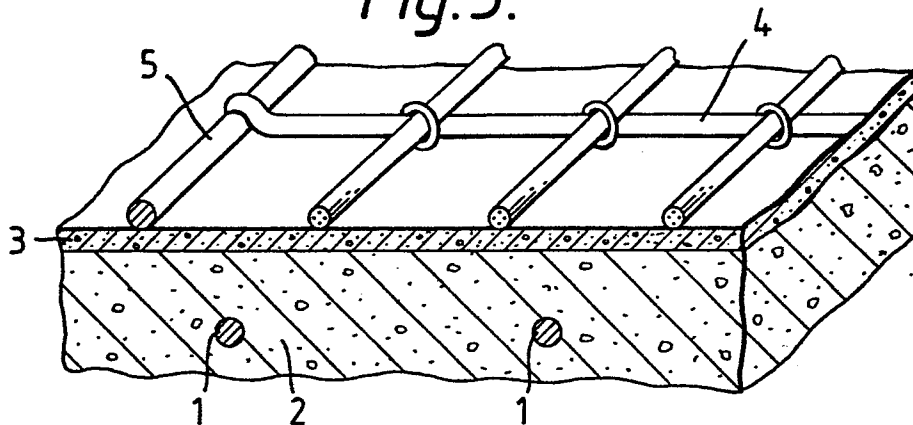


Fig. 4.

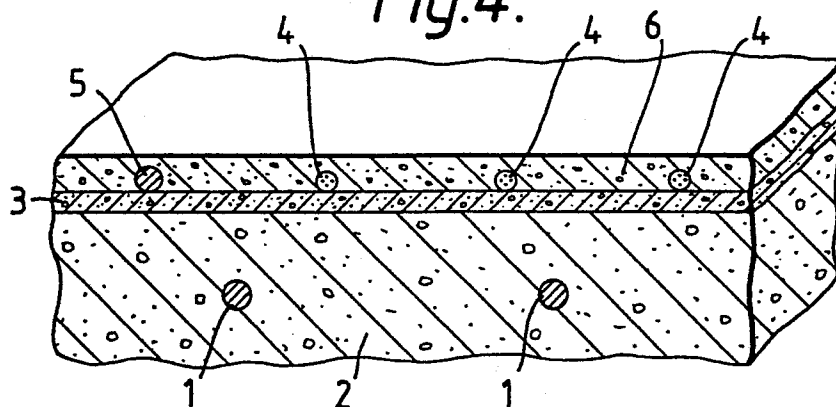


Fig. 5.

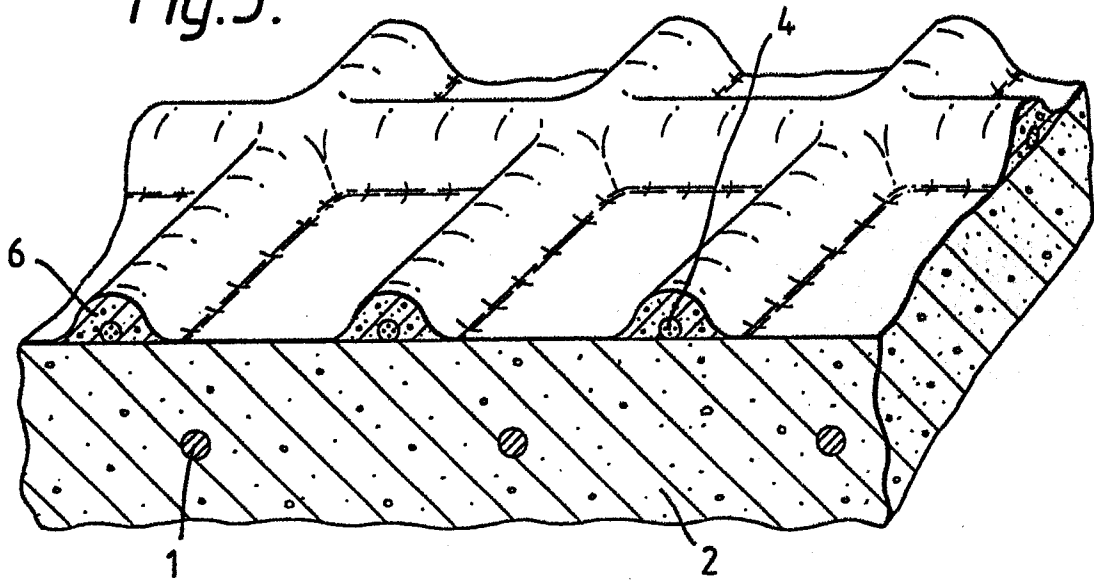


Fig. 6.

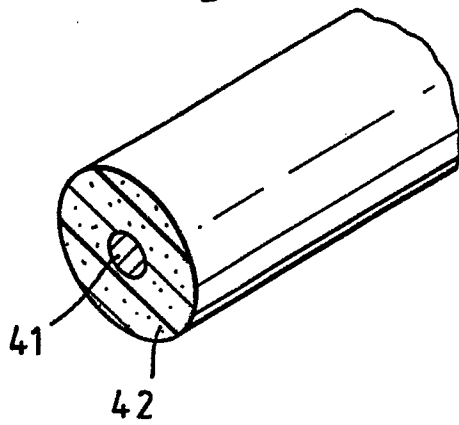


Fig. 7.

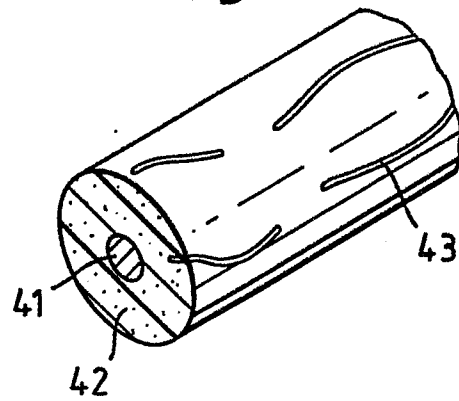


Fig. 8.

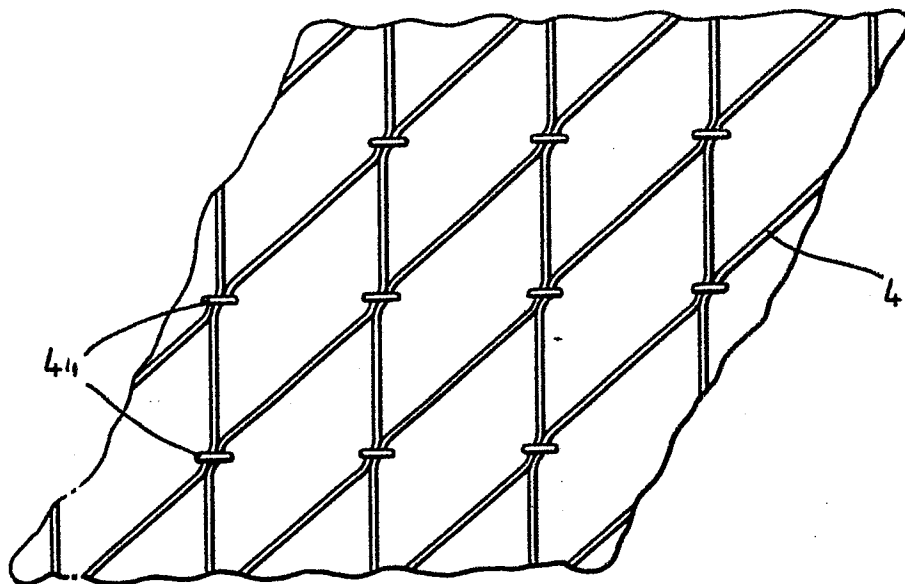
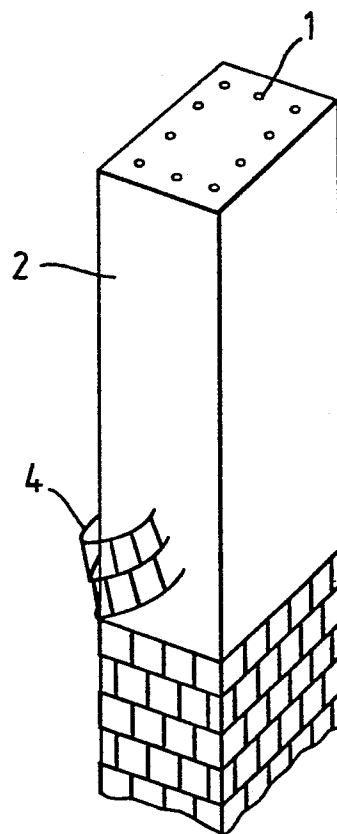


Fig. 9.*Fig. 10.*