

(12) UK Patent Application (19) GB (11) 2 425 778 (13) A

(43) Date of A Publication 08.11.2006

(21) Application No: 0415132.0

(22) Date of Filing: 06.07.2004

(71) Applicant(s):
Gareth Kevin Glass
3 Hillside, LICHFIELD, Staffs, WS14 9DQ,
United Kingdom

(72) Inventor(s):
Gareth Kevin Glass

(74) Agent and/or Address for Service:
Gareth Kevin Glass
3 Hillside, LICHFIELD, Staffs, WS14 9DQ,
United Kingdom

(51) INT CL:
C23F 13/ 16 (2006.01) **C23F 13/ 00** (2006.01)
C23F 13/ 08 (2006.01)

(52) UK CL (Edition X):
C7B BATB BATC B161

(56) Documents Cited:
GB 0670482 A **WO 2000/ 026439 A2**
JP 590140380 A **US 6193857 B1**

(58) Field of Search:
UK CL (Edition X) **C7B**
INT CL⁷ **C23F**
Other:

(54) Abstract Title: **Protection of reinforcing steel**

(57) An anode assembly for the protection of reinforcing steel embedded in a concrete matrix is provided. The anode assembly comprises: a base metal 1, conductor 6 and a flexible conductive tie 4. The base metal 1 is less noble than steel and is coupled to an activating agent. The conductor 6 has fixing point that is connected to the base metal 1 and the flexible conductive tie 4 passes through the fixing point 2. The tie 4 can be wound round the steel 5 to connect the anode assembly to the steel reinforcement 5. A locking mechanism may also be provided on the tie 4.

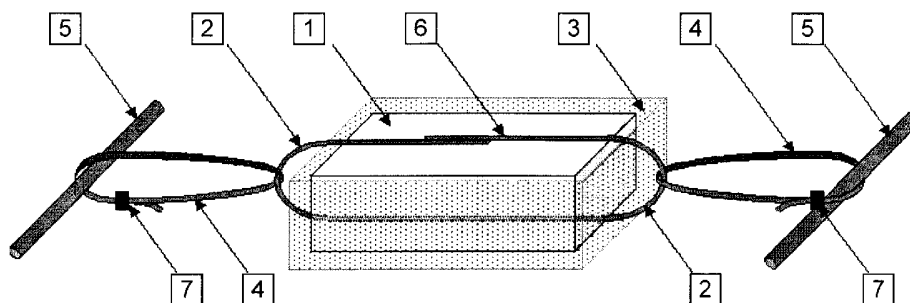


Figure 1

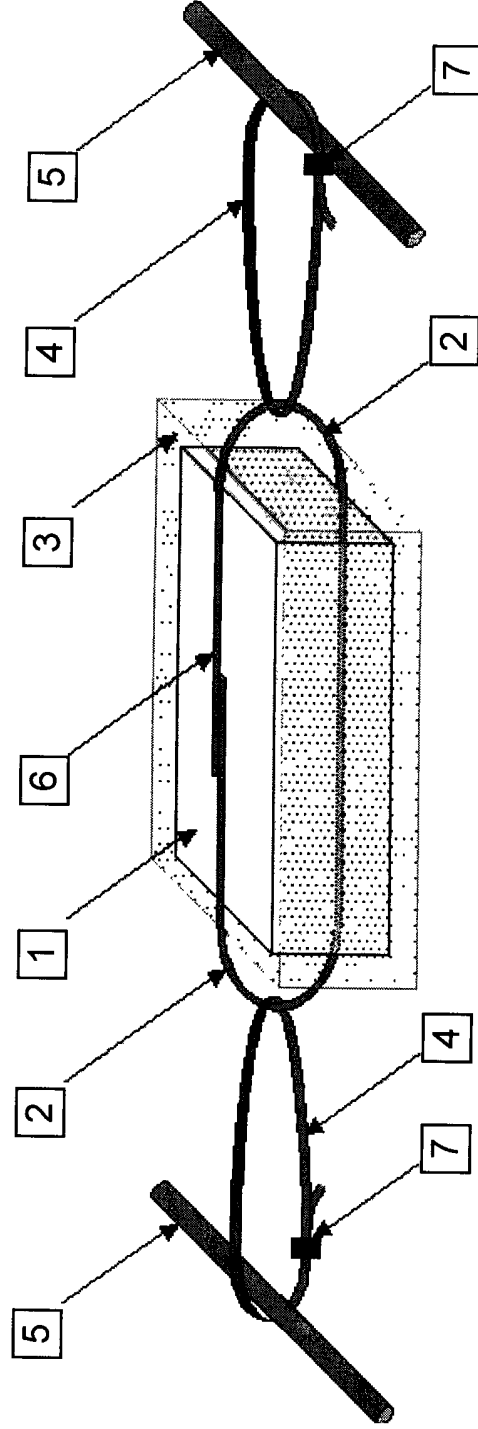


Figure 1

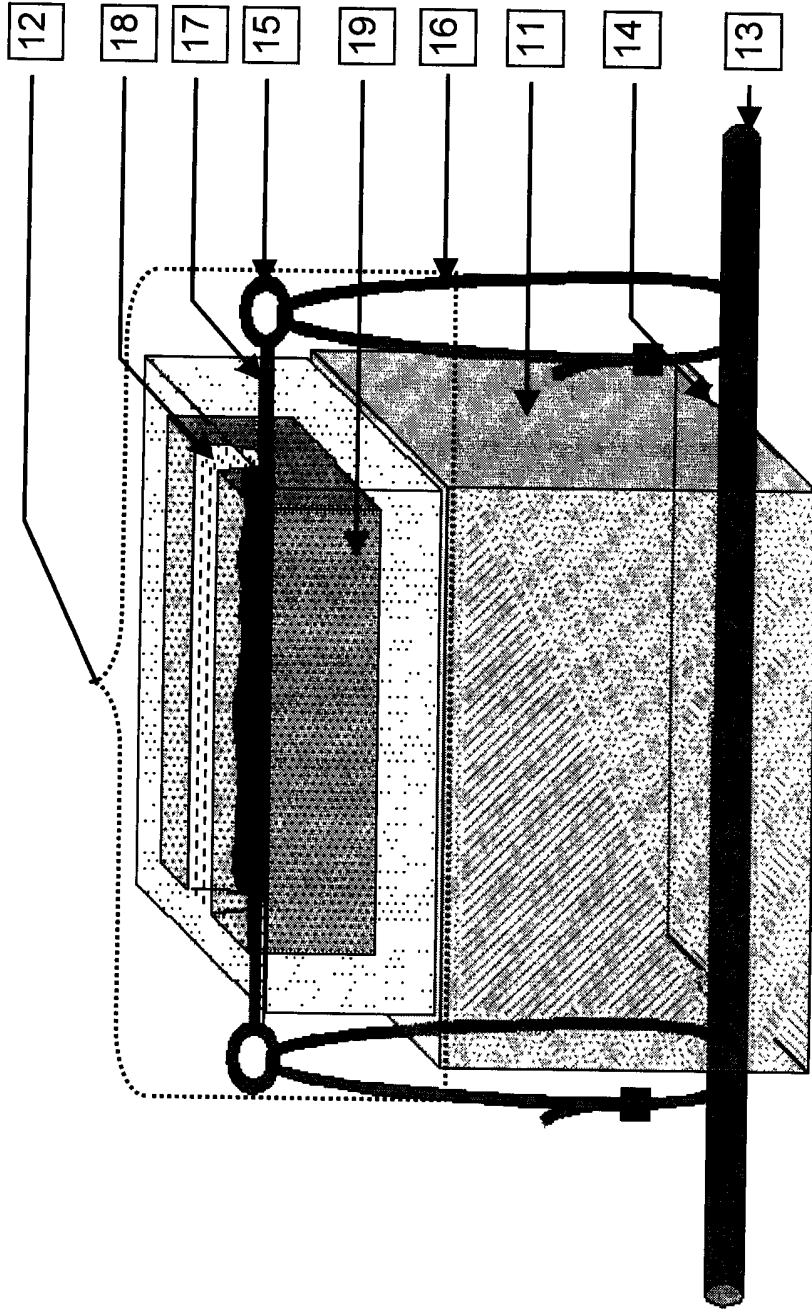


Figure 2

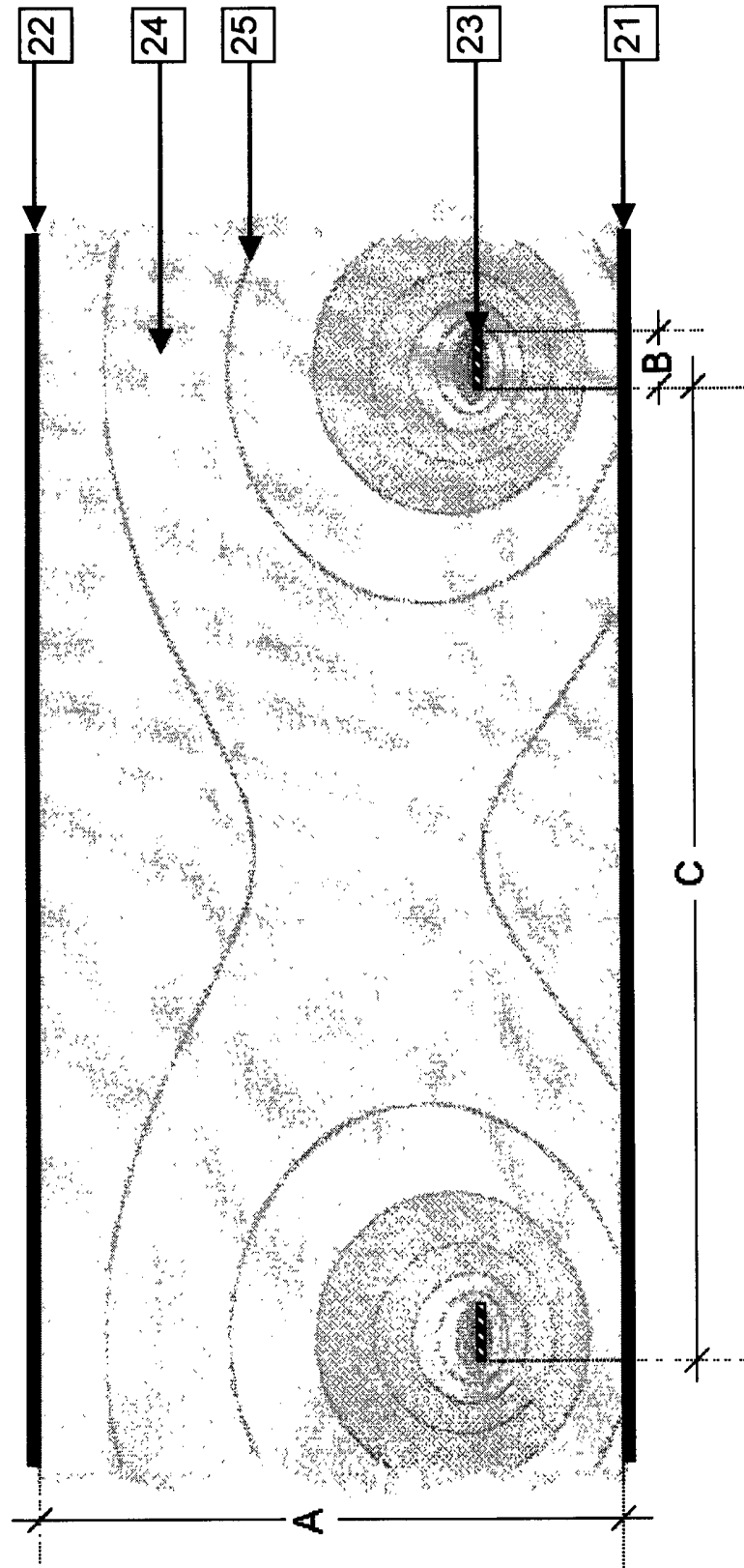


Figure 3

4/9

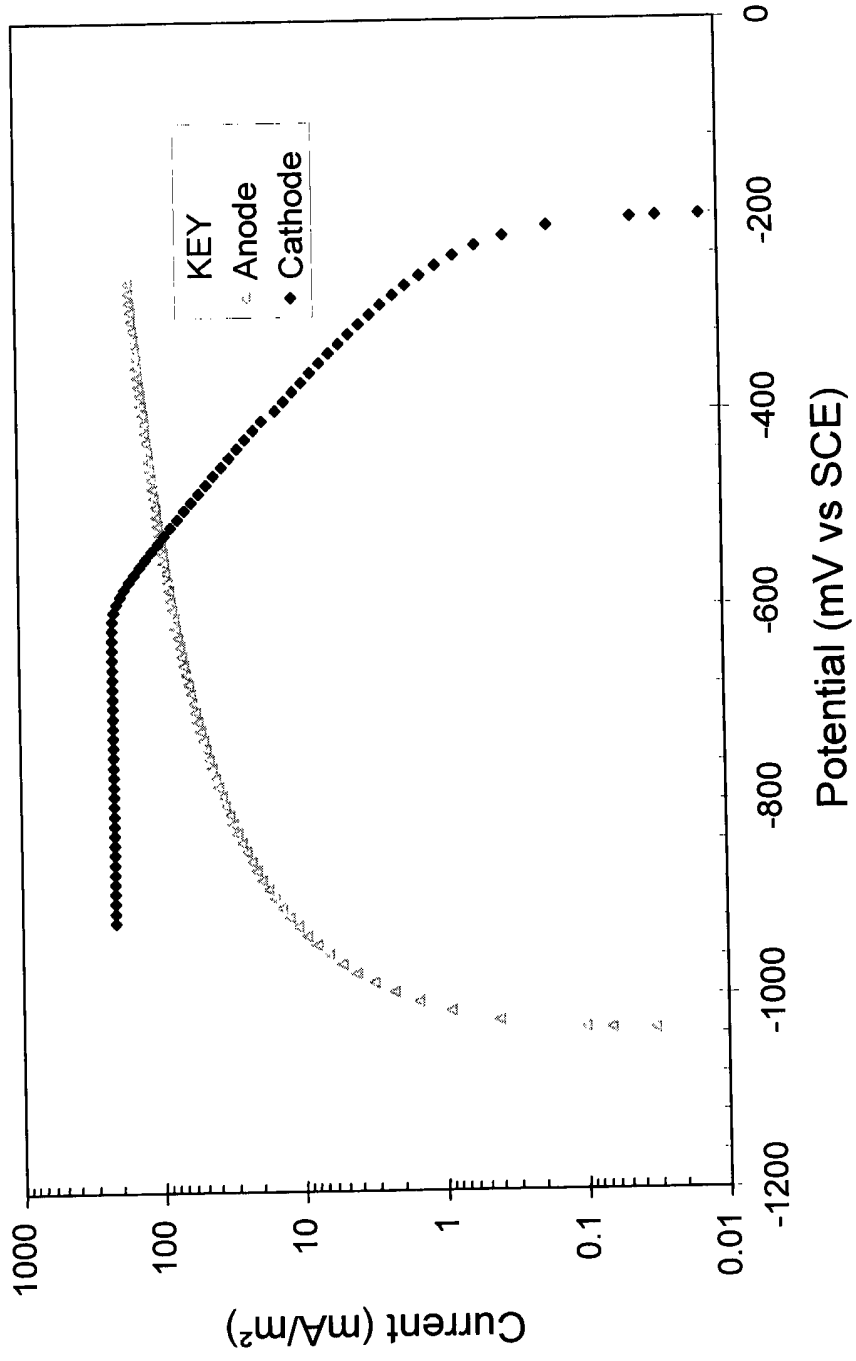


Figure 4

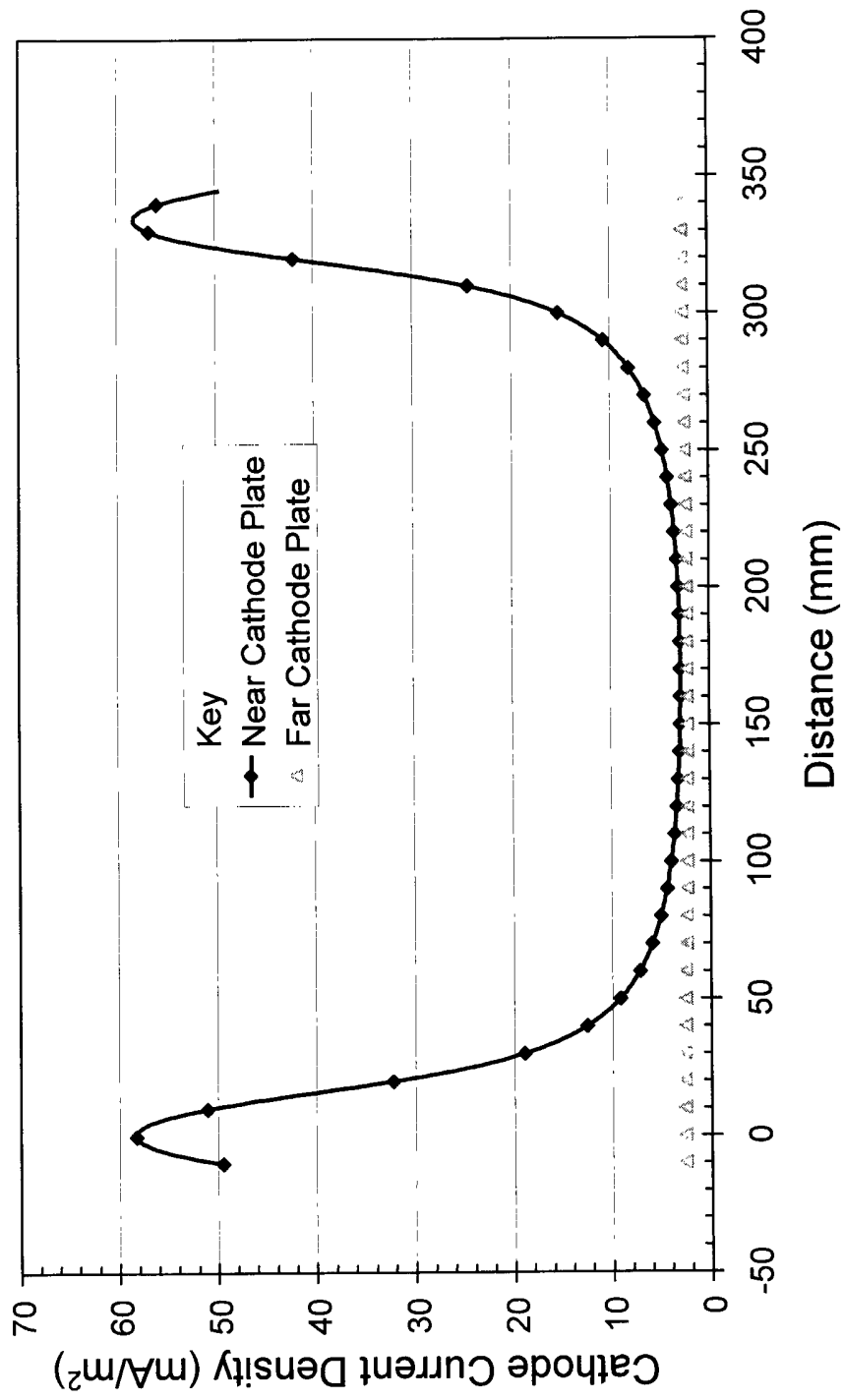
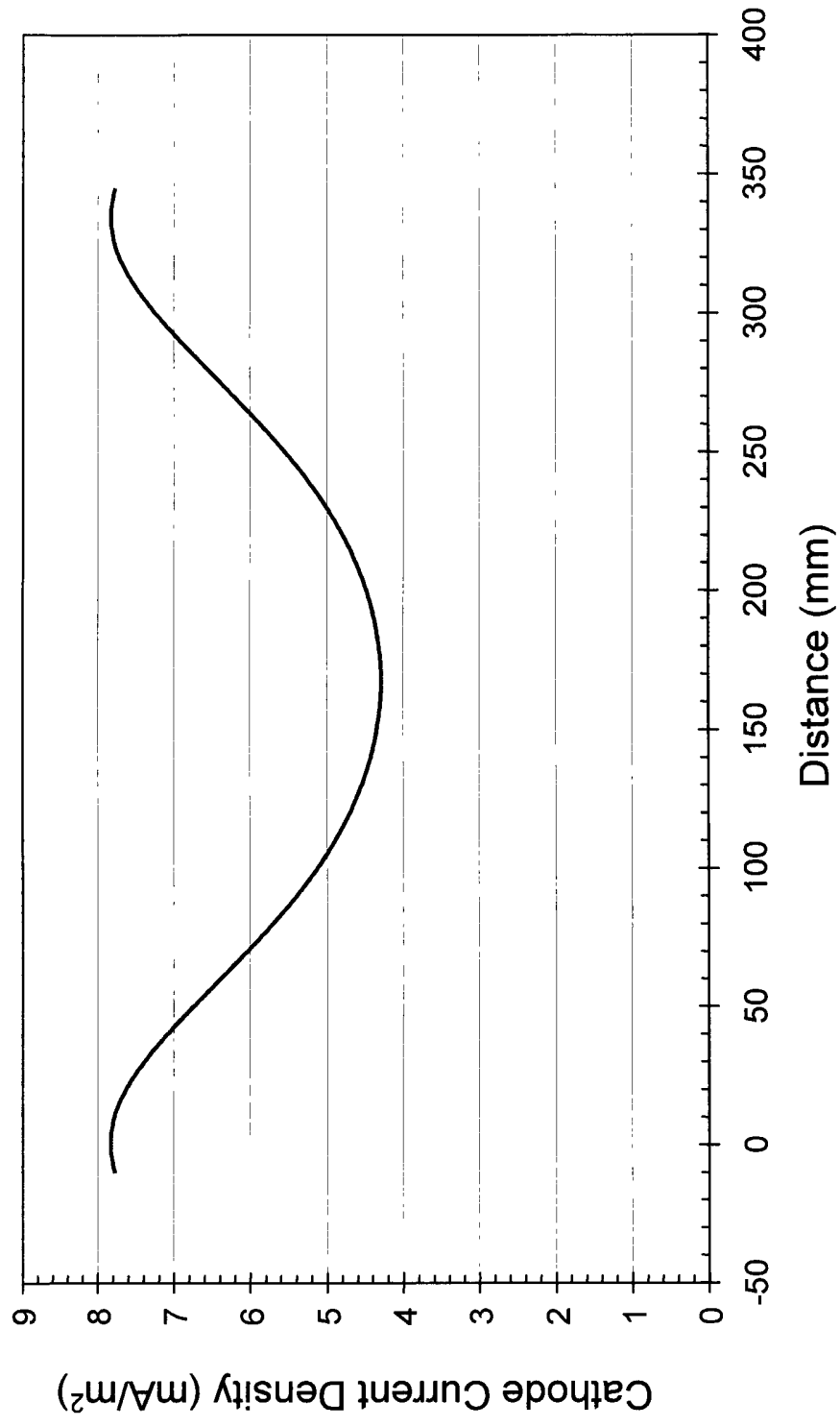
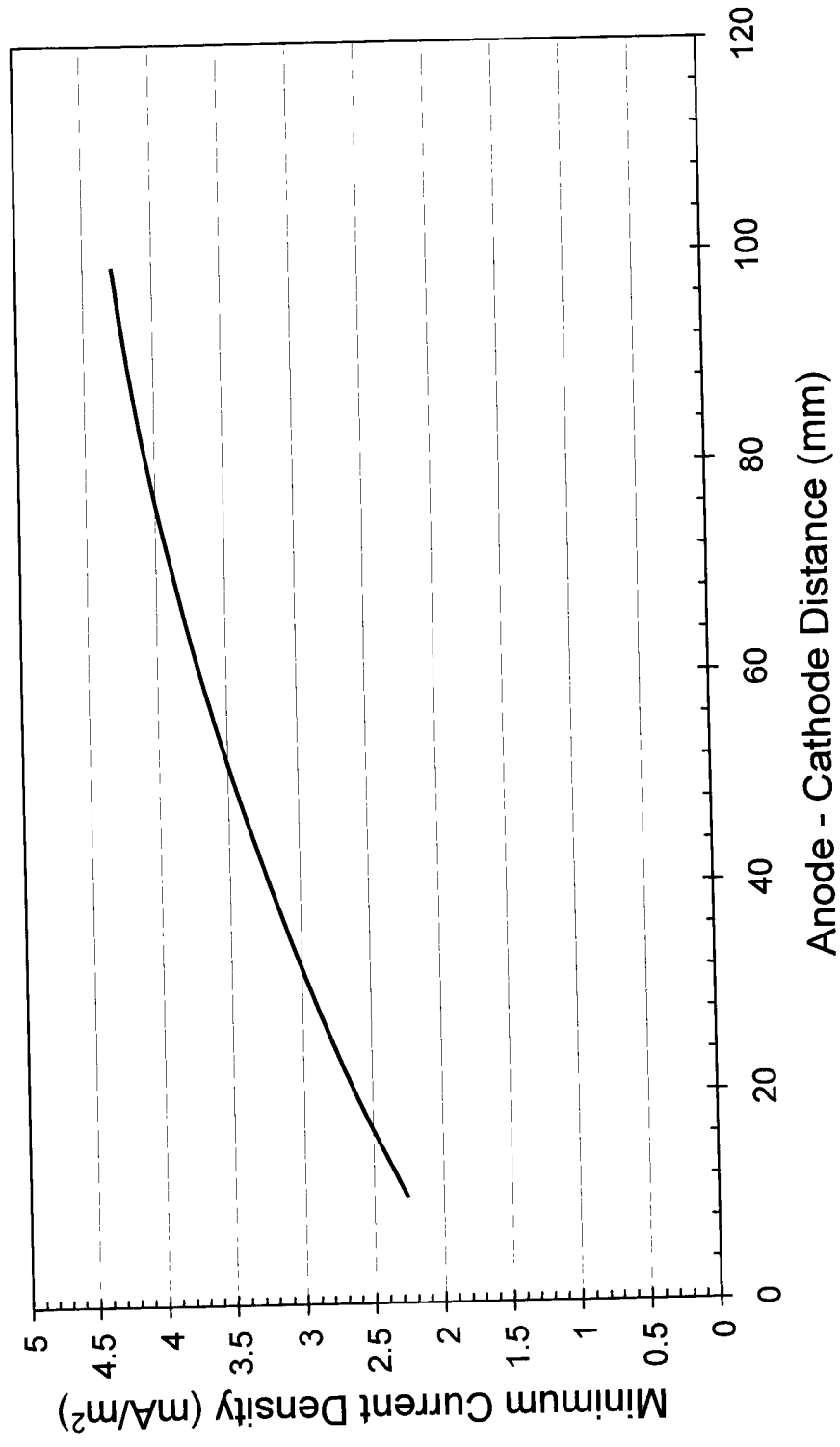


Figure 5

Figure 6



**Figure 7**

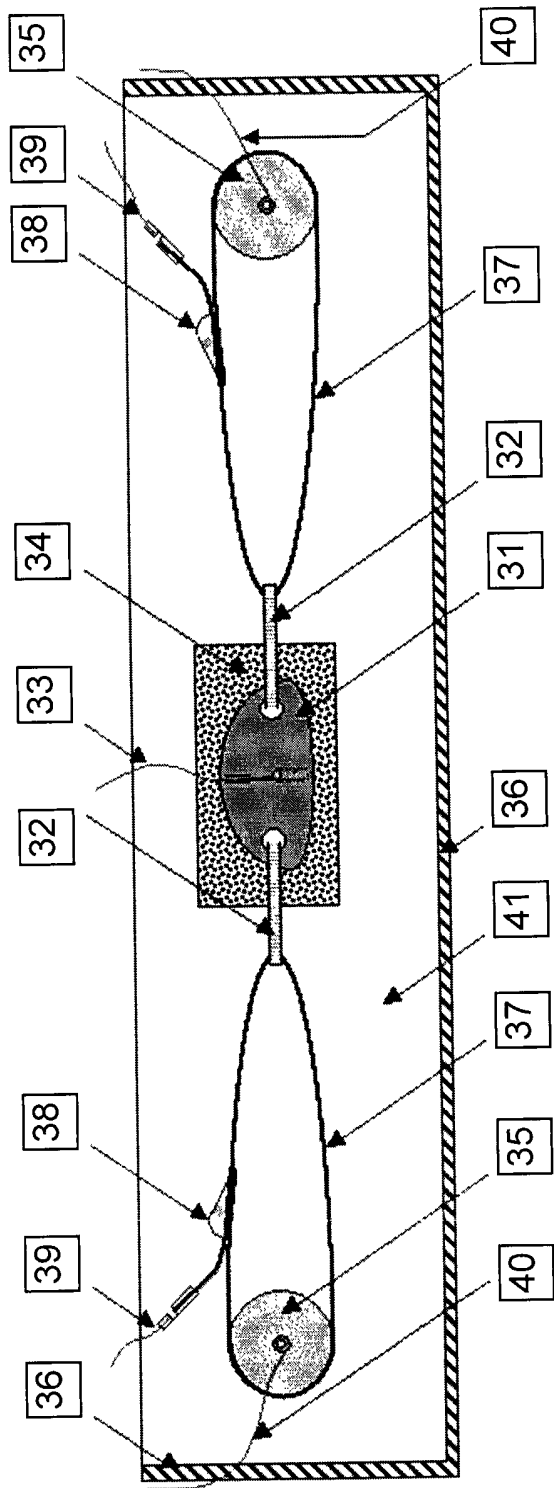


Figure 8

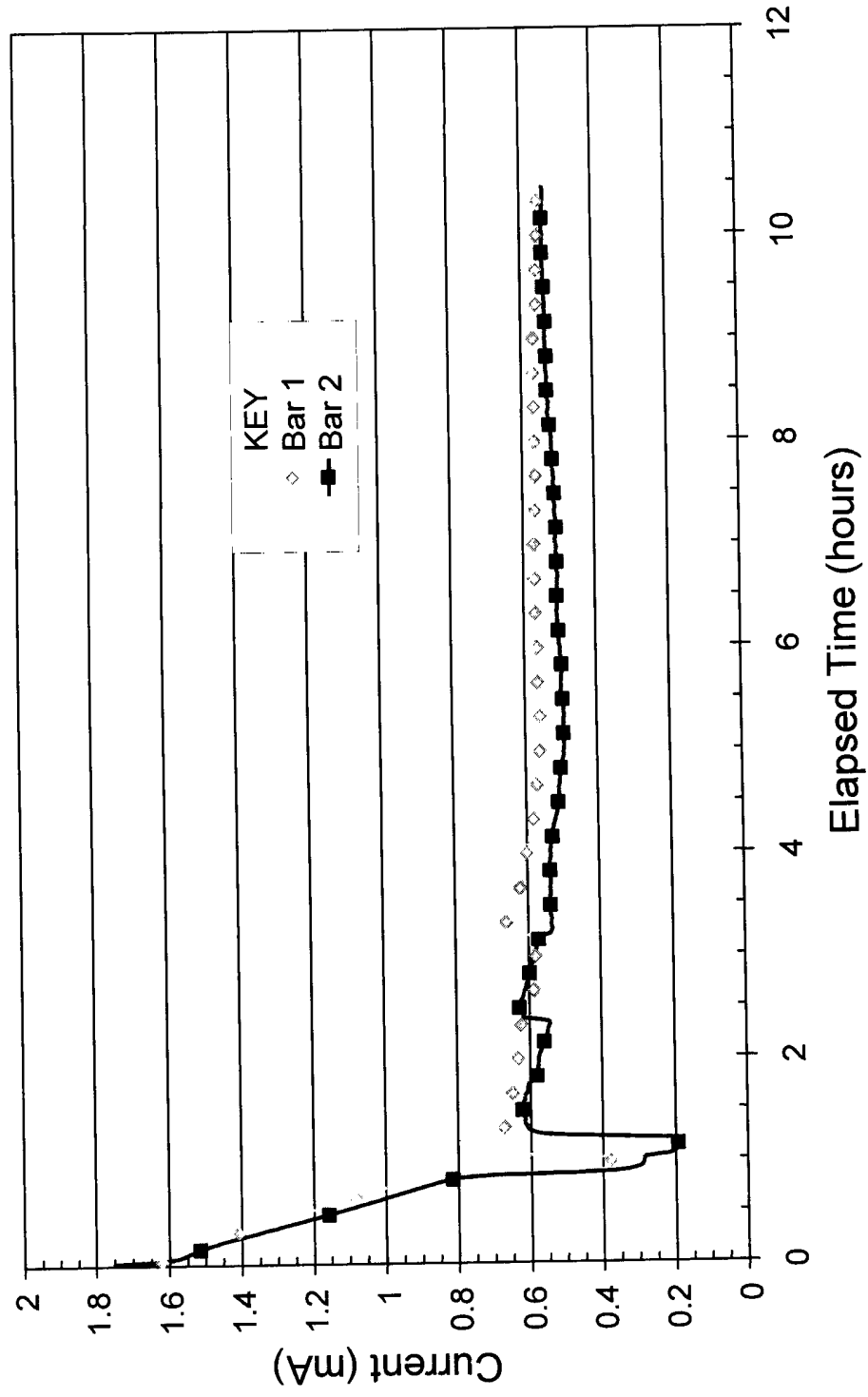


Figure 9

PROTECTION OF REINFORCING STEEL

FIELD OF THE INVENTION

- 5 This invention relates to the protection of steel in concrete using sacrificial anodes and in particular to the connection of sacrificial anodes to steel in concrete and to the method of installing sacrificial anodes in concrete.

BACKGROUND

10

Sacrificial cathodic protection is a technique that is used to control the corrosion of steel in concrete. It involves connecting a base metal that is less noble than steel, such as a metal or alloy of zinc, aluminium or magnesium, to the steel. The base metal is consumed by anodic dissolution and in the process a current flows to the steel which becomes the protected cathode of the base metal - steel couple. US patent number 6193857 shows one arrangement that may be used to achieve this.

15

US patent number 6685822 discloses the use of sacrificial anodes in new concrete construction to protect steel in concrete. The sacrificial anode delivers current to the steel before the concrete has hardened to increase the tolerance of the reinforced concrete to aggressive chloride ion contamination.

20

Sacrificial anode systems exist as surface applied systems or embedded discrete systems. Surface applied anodes are large surface area anodes that deliver relatively low current densities of the order of 10 mA/m² when expressed per unit of anode area. US patent number 6033553 describes a thermally applied zinc coating applied to the surface of the concrete and then treated with a salt solution to enhance the current output of the zinc. US patent number 5714045 describes a zinc mesh held against the surface of the concrete with a jacket filled with mortar. U.S. patent number 5650060 describes a zinc sheet with an ionically conductive adhesive lining that is applied to the surface of the concrete.

25

30

Discrete anodes are individually distinct compact anodes that deliver relatively high current densities of the order of 50 to 250 mA/m² off the anode surface. They are placed in holes in the concrete or are attached to exposed steel in new construction or exposed steel at locations where patch repairs to the concrete are undertaken. Discrete anodes are usually combined with an activating agent. US patent number 6572760 describes an anode formed by pressing together a finely divided material consisting of a metal such as zinc and a humectant. U.S. patent number 6303017

35

describes an anode metal such as zinc with a porous material containing an alkali that is cast around the zinc.

5 The activating agent in contact with the base metal in a sacrificial anode assembly may prevent the anode from drying out or prevent the formation of insoluble products that restrict the dissolution of the base metal. US patent number 6022469 describes the use of KOH and LiOH to prevent zinc passivation that may otherwise result from the deposition of insoluble zinc products. US patent number 6165346 describes the use of LiNO_3 as a deliquescent material to prevent the anode from drying out. US patent
10 number 6217742 describes the use of combinations of LiNO_3 and LiBr to enhance the anode output.

15 In surface applied anode systems the source of protection current is distributed across the surface of the concrete. Current distribution is more complex with discrete sacrificial anodes. Cement & Concrete Composites vol. 24 (2002) pp.159 -167 investigates current distribution from a surface applied anode to embedded steel bars and notes that current distribution is affected by the boundary conditions, the concrete resistivity and the layout of the anode and the steel in the concrete.

20 The connection between the sacrificial anode and the steel reinforcement provides a path for electron conduction between the base metal and the steel. The traditional method involves connecting one end of an electrical conductor to the steel using a clamp, clip or drilled and tapped hole and connecting the other end to the sacrificial anode by soldering or welding. Other methods of connection also exist. US patent
25 number 6193857 describes a method of connecting the anode to the steel which involves forming the anode around a section of a ductile metal conductor and wrapping an exposed section of the ductile metal conductor around the steel. US patent number 6572760 describes a connection detail that involves obtaining contact between the anode and the reinforcing steel by impacting the anode against the steel in a suitably
30 sized hole drilled through the concrete to the steel. US patent number 6572760 also describes a welded connection between the anode and the steel in a hole drilled through the concrete to the steel.

35 This invention is concerned with the method of connection of discrete sacrificial anodes to the steel. It provides an advantageous method for the sacrificial cathodic protection of steel in concrete in situations where the steel bars are exposed such as in new construction and at areas where patches of damaged concrete are removed.

PROBLEM TO BE SOLVED

The connection between the sacrificial anode and the steel reinforcement must be sufficiently robust to withstand the forces imposed on it during concrete placement or repair mortar application. These forces include the physical placement of the concrete or cementitious repair material onto the anode-steel arrangement and the use of compaction tools such as poker vibrators in the concrete mix. It is an advantage if the connection is simple to install on varying steel geometries and allows anode steel arrangements that enhance current distribution to the steel reinforcement.

SUMMARY OF THE INVENTION

According to the present invention there is provided a method of protecting steel in concrete which comprises connecting a conductor with a fixing point such as a loop, hook, eye, hole or opening to a base metal that is less noble than steel, and tying the base metal to the steel in concrete by passing an electronically conductive tie through the fixing point and around the steel reinforcement whereby the tie physically and electronically connects the assembly to the steel reinforcement. The fixing point is preferably located close to the base metal. The base metal is preferably coupled to an activating agent that makes the base metal suitable for use as a discrete anode in the sacrificial protection of reinforcing steel in concrete. The anode will preferably have more than one fixing point and more than one tie to enable it to be held between reinforcing steel bars. The tie preferably has a locking mechanism that restrains its loosening once it has been connected and tightened.

ADVANTAGEOUS EFFECT OF THIS INVENTION

This invention is ideally suited to achieving anode steel geometries that allow advantageous current distribution when the steel bars are exposed. The assembly provides a more adaptable method of attaching sacrificial anodes to exposed steel reinforcement that can cope with the wide range of steel bar geometries encountered in concrete construction while maintaining or improving the simplicity of making the connection when compared with other methods of connection. The flexibility arises as the result of the separation of the tie from the rest of the anode assembly. This allows the tie to be selected when the physical properties required by the application are known. Manufacture and packaging of the anode assembly is also simplified by splitting the electronic and physical connection of the base metal to the steel into a fixing point and tie as the anodes do not need to be attached to long fixing wires of variable lengths.

BRIEF DESCRIPTION OF THE DRAWINGS.

5 Figure 1 shows one arrangement of the anode assembly connected between two reinforcing steel bars that utilises a wire loop to form a fixing point.

Figure 2 shows a second arrangement of the anode assembly connected to one reinforcing steel bar that may be used to enhance current distribution.

10 Figure 3 shows a section through the arrangement of anodes and cathodes that was investigated in Example 1.

Figure 4 shows the polarisation curves that were used to describe the anode and cathode boundary conditions in Example 1

15 Figure 5 shows the predicted current distribution to the cathodes when the anodes are located 10 mm from the closest cathode in Example 1

20 Figure 6 shows the predicted current distribution to the cathodes when the anodes are located midway between the two cathodes in Example 1.

Figure 7 shows the change in the minimum current density received by the cathode when the anode-cathode distance is varied from 10 to 99 mm in Example 1.

25 Figure 8 shows the anode assembly arrangement that was used to monitor the anode output in Example 2.

Figure 9 shows a graph of the output of the anode assembly in Example 2.

30 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

One arrangement of the sacrificial anode assembly is given in Figure 1. Referring to Figure 1, the discrete sacrificial anode assembly comprises a base metal [1] that is less noble than steel, a fixing point connected to the base metal [2], an activating medium in contact with the base metal [3] and a tie [4] which passes through the fixing point [2] and around the steel [5].

The base metal [1] is a metal or alloy such as zinc, aluminium or magnesium or alloys thereof that will corrode in preference to steel when they are connected together. The

activating medium [3] is a medium that contains an activating agent to assist the dissolution of the base metal in the concrete environment. Examples of activating agents include LiBr, KOH, and LiOH.

- 5 The fixing point [2] is a loop, hook, eye, hole or opening that may be formed by an electrical conductor [6] connected to the base metal [1]. Figure 1 shows an example of a conductor with a loop [2] that was formed by connecting the conductor to the base metal. A conductive fixing point may also be connected to a short length of conductor that is connected to the base metal. The fixing point [2] is preferably located close to
10 the base metal [1] to maximise the adjustment that can be accommodated by varying the length of the tie [4]. Methods of connecting the conductor [6] to the base metal [1] include soldering, brazing and welding. This connection is preferably insulated from the external environment with an insulating coating such as an epoxy coating. The base metal [1] may also be formed around a part of the conductor [6] with the fixing
15 point [2] to achieve an electrical connection. This may be achieved by casting the base metal around part of the conductor.

The tie [4] is a bendable or flexible electrical conductor that passes through the fixing point [2] and is used to physically tie the assembly to the steel [5] and in the process
20 make an electrical connection between the base metal and the steel. This connection allows electrons to move between the base metal and the steel. The tie gives the anode assembly its flexibility as the length of the tie is variable. This allows a wide range of fixing arrangements to be accommodated. Examples of the tie [4] include a metallic cable tie and a bendable wire. The tie preferably has a locking mechanism [7]
25 that restrains its loosening once it has been connected and tightened. Examples of a self locking mechanism, present on metallic cable ties, are given in US patent number 6076235 and US patent number 6647596. Other locking mechanisms would also be suitable. The strength and length of the tie can be selected when details of the application are known. Stainless steel cable ties are available with strengths ranging
30 from 500 to 2500 N and lengths ranging from 100 to 1000 mm.

The fixing point [2], conductor [6] and the tie [4] are made from a material that will conduct electrons. This material is preferably a metal, although in theory a material like carbon can also be used. The preferred metal is one that will be cathodically protected
35 by the base metal [1]. Examples include steel and stainless steel.

To achieve an advantageous current distribution it is preferable to locate the base metal as far from the steel surface as possible. This may be achieved by positioning the base metal midway between a pair of steel bars using ties as shown in Figure 1.

After the assembly has been formed and attached to the steel it would typically be surrounded by a concrete or cementitious repair material.

Figure 2 shows a second method of achieving an advantageous current distribution.

5 This is obtained by placing a porous spacer [11] between the anode [12] and the steel [13] to which the anode is tied. The porous spacer preferably has a higher resistivity than the concrete that will be cast around the anode and the steel. This moves the anode away from the steel by the dimension of the spacer. In addition, the higher resistivity of the spacer discourages the flow of large currents directly to the closest
10 steel under the spacer. The porous spacer is preferably shaped to facilitate its installation between the anode and the steel. The shape of the spacer could, for example, include an indentation [14] in which to locate the steel bar.

Figure 2 also shows an alternative fixing point. An eye [15] forms the fixing point to
15 hold the tie [16]. The conductor [17] with the eye is connected to the base metal in an indentation [18] in the base metal [19]. The indentation [18] is preferably filled with an insulating filler to provide further protection for the connection.

Specific features of this invention are illustrated with the following examples.

20

Example 1

This example shows the effect of anode placement on current distribution in reinforced concrete. It is investigated using a mathematical model. Figure 3 shows a section
25 through the arrangement that was modelled. It consists of two parallel cathode plates ([21] and [22]) 200 mm apart with 30 mm wide anode strips [23] located between cathode plates at 334 mm intervals. These dimensions (200, 30 and 334 mm) are labelled A, B and C respectively in Figure 3. A medium with a resistivity of 200 Ωm that represents concrete [24] fills the space between the anodes and the cathodes. The
30 anode strips [23] are 2 mm thick and are all spaced off the cathode plate [21] by the same distance of concrete which varies between 10 and 99 mm in this example. The area of the anode is approximately one tenth that of the cathode. This arrangement is modelled on a 1 mm square grid using a finite difference method that is constrained by the need to conserve current at all points between the anode and cathode. This
35 constraint is used to generate a pair of correction factors for each point on the grid to accelerate convergence of the model. The type of mathematical model is not critical to the findings and finite element or boundary element models may be used to obtain similar results. An example of the potential contours [25] resulting from the model when the anode is spaced 50mm from the cathode is included in Figure 3.

Figure 4 shows two curves representing the potential-current relationship at the anode (also referred to as the anodic polarisation curve) and the cathode (also referred to as the cathodic polarisation curve) that are used to describe the boundary conditions at the anode and cathode respectively. All electrode potentials are given relative to the saturated calomel electrode (SCE).

The anodic polarisation curve in Figure 4 represents the mixed potential-current relationship of an anodic and a cathodic reaction occurring locally on the anode. The anodic reaction on the anode is described by an equilibrium potential of -1114 mV, an exchange current density of 0.1 mA/m^2 at the equilibrium potential, an anodic Tafel slope of 60 mV and an approach resistance of $4 \Omega\text{m}^2$. The approach resistance may be viewed as the resistance to migration through a layer of anodic reaction products at the anode surface. The cathodic reaction on the anode is described by a limiting cathodic current of 1 mA/m^2 . The combined effect of these two reactions on the anode gives an anode with an open-circuit local corrosion rate of 1 mA/m^2 and a corrosion potential of -1050 mV. This is used to model the behaviour of a zinc anode.

The cathodic polarisation curve in Figure 4 represents the mixed potential-current relationship of an anodic and a cathodic reaction occurring locally on the cathode. The cathodic reaction on the cathode is described by an equilibrium potential of -33 mV, an exchange current density of 0.1 mA/m^2 at the equilibrium potential, a cathodic Tafel slope of 167 mV and a limiting current of 200 mA/m^2 . The anodic reaction on the cathode is described by a limiting anodic current of 1 mA/m^2 . The combined effect of these two reactions on the cathode gives a cathode with an open-circuit local corrosion rate of 1 mA/m^2 and a corrosion potential of -200 mV. This is used to model the behaviour of a steel cathode.

The boundary conditions described above at the anode and cathode are solved by iteration as part of the model. Similar results may be obtained by extracting the data from Figure 4 and feeding it directly into the model.

Figure 5 shows one set of results obtained by the model. It gives the current density applied to the near and far cathode plates as a function of distance across the cathode plate. The anode strip is spaced off the near cathode plate by 10 mm of concrete. The anodes are spaced off the cathode plates at positions 0 and 334 mm in Figure 5. It is evident that when the anode is separated from the cathode by only 10 mm, the current density varies widely over the cathode. This represents a very inefficient use of the

anode as some areas of the cathode will be overprotected while others may not receive enough current to achieve protection.

5 Figure 6 shows the current density applied to the cathode plates when the anode strip is spaced off the nearest cathode plate by 99 mm of concrete. In this case the 2 mm thick anode strip is located midway between the cathode plates and the current distribution over the two cathode plates is identical. It is evident that, when the anode is separated from the cathode by 99 mm, the current density variation over the cathode is relatively small. This represents a much more efficient use of the anode than that
10 given in Figure 5.

Figure 7 shows the current density applied to the cathode at its furthest point from the anode plotted as a function of the distance separating the anode and the nearest cathode plate. This location on the cathode receives the lowest current density. As the
15 anode is moved away from the nearest cathode plate (10 to 99 mm), the current received at this location increases from 2.3 mA/m^2 to 4.3 mA/m^2 . This represents a significant improvement in the protection afforded to this point on the cathode. An analysis of Figure 5 shows that, when the anode is spaced 10 mm off the cathode, only 28% of the cathode area will receive an applied current density greater than or equal to
20 the minimum current density (4.3 mA/m^2) received by the cathode when the anode is located 99 mm off the cathode.

This example illustrates the significant advantages to be obtained by increasing the distance between sacrificial anodes and protected steel in concrete.

25

Example 2

A sacrificial anode assembly was produced and the output of the anode assembly to a pair of steel bars in concrete was monitored. Figure 8 shows the arrangement that was
30 used. Zinc in the shape of approximately half a sphere of diameter 46 mm and weight 223 g formed the base metal [31] of the anode. Two 4 mm diameter holes were drilled through the zinc at 5 mm from opposite edges of the flat surface of the zinc. An electrically insulating plastic cable tie was passed through each hole to form two insulating plastic loops [32] on opposite sides of the flat zinc surface. These insulated
35 fixing points are needed to facilitate electric current monitoring. Another hole 3 mm in diameter was drilled 5 mm from the edge of the flat surface of the zinc between the insulating plastic loops. A galvanised steel wire of diameter 1.5 mm was passed through the 3 mm hole and then twisted back on itself and pulled into the hole to create a tight and robust electrical connection to the zinc anode. The connection was

insulated with silicone grease. An end of the galvanised wire was connected to a sheathed 1.5 mm² copper wire [33] by means of an insulated connector.

5 An ordinary Portland cement (OPC) mortar was made using a 3.4% LiBr solution in the place of clean water. The cement / fine sand / LiBr solution mix proportions expressed as a weight ratio were 1/2/0.6 respectively. The mortar [34] was cast around the zinc in a wooden mould that had internal dimensions of 65 x 65 x 50 mm. A portion of the plastic loops and the electrical cable extended beyond this mould. This produced an activated zinc sacrificial anode with dimensions of 65 x 65 x 50 mm with insulating
10 plastic loops protruding from the opposing 65 x 50 mm faces and an electric cable connected to the zinc protruding from the top surface of the anode.

A wooden mould with internal dimensions of 100 mm high, 325 mm wide and 90 mm deep held two 11mm diameter, 110 mm long ribbed steel bars [35] 220 mm apart and
15 50 mm above the base of the mould. This was achieved using four 11 mm holes drilled through the 100 x 325 mm faces of the mould. The ends of the bars protruded through these holes. A 100 mm high, 325 mm wide section of the mould [36] is shown in Figure 8. The activated zinc sacrificial anode was located in the centre of the mould and tied to the steel bars [35] using two locking stainless steel cable ties 4.25 mm wide
20 by 0.25 mm thick by 200 mm long [37]. The stainless steel cable ties passed through the plastic loops [32] and around the steel as shown in Figure 8. The stainless steel cable ties [37] were tightened by hand and a locking mechanism [38] restrained the loosening of the ties.

25 Sheathed 1.5 mm² copper core electrical cables [39] were connected to the loose end of each of the stainless steel cable ties using female push on spade connectors crimped to the copper core of the cable. This connection was insulated with silicone grease. Additional electrical cables [40] were connected to the ends of the steel bars for monitoring purposes. These connections were made by drilling a 4 mm diameter
30 hole to a depth of 10 mm into the end of the steel bar and inserting a length of exposed copper core at the end of the sheathed 1.5 mm² copper core electrical cable, together with a 3.5 mm metallic pop rivet, into the hole. The pop rivet was installed with a rivet gun to create an electrical connection between the steel and the copper wire. The connection was insulated with silicone grease.

35

The mould was filled with concrete [41]. The concrete mix consisted of OPC, aggregate and water. The aggregate was graded 0 to 20 mm all-in ballast supplied by "Mix-it" and sourced from a builders merchant. The OPC/aggregate/water mix proportions expressed as a weight ratio were 25/100/13 which produced a general

purpose concrete mix. The steel bars were exposed to the concrete for a length of 90 mm. All the electrical cables extended beyond the mould.

- 5 The resistance between each coated stainless steel cable tie and the steel bar to which it was tied was measured using the electrical cables connected to the steel and the stainless steel cable ties and a general purpose multimeter. The resistance values determined were approximately 0.3Ω indicating that a good electrical connection could be obtained by this method.
- 10 The anode was connected to each of the steel bars through separate 10Ω resistors using the electrical cables connected to the steel bars and the electrical cable connected to the anode. The voltage across the resistors was logged and converted to a current. The current to each of the steel bars labelled Bar 1 and Bar 2 is given in Figure 9. The anode was generating more than 1 mA in this test which is equivalent to
- 15 approximately 200 mA/m^2 of zinc surface area. The current was evenly distributed between the two bars. This level of current would be adequate to protect more than 0.1 m^2 of steel surface in many aggressive situations in reinforced concrete.

CLAIMS

1. An anode assembly comprising:
 - i) A base metal less noble than steel coupled to an activating agent to make it active in concrete,
 - ii) A conductor with a fixing point connected to the base metal,
 - iii) A flexible conductive tie that is passed through the fixing point.
2. An anode assembly as claimed in claim 1 where the flexible conductive tie is passed around the steel reinforcement.
3. An anode assembly as claimed in any one of the above claims with more than one flexible conductive tie.
4. An anode assembly as claimed in claim 3 with more than one fixing point.
5. An anode assembly as claimed in any one of the above claims where the length of the conductor between the base metal and the fixing point is less than 150 mm.
6. An anode assembly as claimed in claim 5 where the length of the conductor between the base metal and the fixing point is less than 100 mm.
7. An anode assembly as claimed in claim 5 where the length of the conductor between the base metal and the fixing point is less than 50 mm.
8. An anode assembly as claimed in any one of the above claims where the tie has a locking mechanism.
9. An anode assembly as claimed in claim 8 where the locking mechanism allows the tie to be tightened and restrains the tie from being loosened.
10. An anode assembly as claimed in any one of the above claims where the fixing point is a loop, hook, eye or hole.
11. An anode assembly as claimed in any one of the above claims where a spacer is placed between the base metal and the protected steel.
12. A method of protecting steel in concrete which comprises the following steps in any order:
 - i. Connecting a conductor with a fixing point to a base metal less noble than steel,
 - ii. Tying the base metal to steel with a flexible conductive tie that is passed through the fixing point and around the steel,
 - iii. Casting the base metal and steel in concrete or a cementitious mortar.
13. A method of protecting steel in concrete as claimed in claim 12 which comprises coupling a base metal to an activating agent to make it active in concrete,
14. A method as claimed in claims 12 or 13 where the base metal is connected to the steel using more than one conductive tie.
15. A method as claimed in claim 14 where the base metal is connected to the steel with more than one fixing point.

16. A method as claimed in claims 14 or 15 where the base metal is held between steel bars.
17. A method as claimed in any one of claims 12 to 16 where the length of the conductor between the base metal and the fixing point is less than 150 mm.
- 5 18. A method as claimed in claim 17 where the length of the conductor between the base metal and the fixing point is less than 100 mm.
19. A method as claimed in claim 17 where the length of the conductor between the base metal and the fixing point is less than 50 mm.
20. A method as claimed in claims 12 or 13 where the tie has a locking mechanism.
- 10 21. A method as claimed in claim 20 where the locking mechanism allows the tie to be tightened and restrains the tie from being loosened.
22. A method as claimed in claims 12 or 13 where the fixing point is a loop, hook, eye or hole.
- 15 23. A method as claimed in claims 12 or 13 where the base metal is spaced off the reinforcement bar with a spacer.

Amendments to the claims have been filed as follows:

13

CLAIMS

- 1 A sacrificial anode assembly for use in the protection of steel in concrete comprising at least in part
a fixing point formed at least in part by a portion of a conductor connected to a base metal in contact with an activating agent and
a separate conductive tie that is used to tie the fixing point to the steel to hold the anode assembly in place where
the tie is sufficiently conductive such that an electrical connection between the steel and conductor via the tie is achieved by passing the tie through the fixing point and around the steel and
the fixing point is sufficiently open to allow the tie to be passed through the fixing point and to allow the length of the tie extending from the fixing point to be adjusted.
- 2 An assembly as claimed in claim 1 where the fixing point is located close to the base metal such that the fixing point is no more than 100 mm from the base metal to maximise the adjustment possible by varying the length of the tie.
- 10 3. An anode assembly as claimed in any one of the above claims with more than one flexible conductive tie.
4. An anode assembly as claimed in claim 3 with more than one fixing point.
5. An anode assembly as claimed in any one of the above claims where the length of the conductor between the base metal and the fixing point is less than 150 mm.
- 15 6. An anode assembly as claimed in claim 5 where the length of the conductor between the base metal and the fixing point is less than 100 mm.
7. An anode assembly as claimed in claim 5 where the length of the conductor between the base metal and the fixing point is less than 50 mm.
8. An anode assembly as claimed in any one of the above claims where the tie has a locking mechanism.
- 20 9. An anode assembly as claimed in claim 8 where the locking mechanism allows the tie to be tightened and restrains the tie from being loosened.
10. An anode assembly as claimed in any one of the above claims where the fixing point is a loop, hook, eye or hole.
- 25 11. An anode assembly as claimed in any one of the above claims where a spacer is placed between the base metal and the protected steel.
12. A method of protecting steel in concrete which comprises the following steps in any order:
 - i. Connecting a conductor with a fixing point to a base metal less noble than steel,
 - 30 ii. Tying the base metal to steel with a flexible conductive tie that is passed through the fixing point and around the steel,
 - iii. Casting the base metal and steel in concrete or a cementitious mortar.
13. A method of protecting steel in concrete as claimed in claim 12 which comprises coupling a base metal to an activating agent to make it active in concrete,
- 35 14. A method as claimed in claims 12 or 13 where the base metal is connected to the steel using more than one conductive tie.
15. A method as claimed in claim 14 where the base metal is connected to the steel with more than one fixing point.

16. A method as claimed in claims 14 or 15 where the base metal is held between steel bars.
17. A method as claimed in any one of claims 12 to 16 where the length of the conductor between the base metal and the fixing point is less than 150 mm.
- 5 18. A method as claimed in claim 17 where the length of the conductor between the base metal and the fixing point is less than 100 mm.
19. A method as claimed in claim 17 where the length of the conductor between the base metal and the fixing point is less than 50 mm.
20. A method as claimed in claims 12 or 13 where the tie has a locking mechanism.
- 10 21. A method as claimed in claim 20 where the locking mechanism allows the tie to be tightened and restrains the tie from being loosened.
22. A method as claimed in claims 12 or 13 where the fixing point is a loop, hook, eye or hole.
- 15 23. A method as claimed in claims 12 or 13 where the base metal is spaced off the reinforcement bar with a spacer.



15



INVESTOR IN PEOPLE

Application No: GB0415132.0

Examiner: Miss Marian Challis

Claims searched: 1-23

Date of search: 27 May 2005

Patents Act 1977: Search Report under Section 17**Documents considered to be relevant:**

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-3, 8-10, 12-14, 20-22	US 6193857 B1 (DAVISON) Figures 1-4, columns 2-5
X	1-3, 8-10	WO 00/26439 A2 (FOSROC) Figures 1-3, pages 2-5
X	1, 5-7, 17-19	JP 59140380 A (NIHON) Figures 1-3, Abstract WPI AN: 1984-234549
X	1	GB 670482 A (ABBEY) Figures 1-3, pages 2 and 3

Categories:

X Document indicating lack of novelty or inventive step	A Document indicating technological background and/or state of the art.
Y Document indicating lack of inventive step if combined with one or more other documents of same category.	P Document published on or after the declared priority date but before the filing date of this invention.
& Member of the same patent family	E Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

C7B

Worldwide search of patent documents classified in the following areas of the IPC⁰⁷

C23F

The following online and other databases have been used in the preparation of this search report
PAJ, WPI, EPODOC and the Internet