

A METHOD FOR GALVANIC PROTECTION OF A CONCRETE STRUCTURE

[0001] The invention relates to reinforced concrete techniques, and more particularly to a method of protecting armatures of concrete against corrosion.

[0002] The steel armatures of reinforced concrete corrode because of the pH decrease of the concrete in which they are embedded in case of carbonation, and/or of penetration by diffusion of polluting products such as chlorides for instance. These phenomena which cause corrosion may happen even with a low humidity rate.

[0003] To place the armatures in an immunizing medium which protects them again, a typical method consists in scratching off the covering concrete to replace it with healthy concrete. But this method is expensive.

[0004] To protect the armatures in their original environment, techniques related to chemistry can be used, such as the application of inhibiting products, or related to electrochemistry, such as methods for cathodic or galvanic protection.

[0005] The corrosion inhibitors are liquid products which, once applied on the concrete surface, migrate by diffusion through the latter and attach onto the armatures. They inhibit the cathodic or anodic reactions or, for some of these products, they inhibit both (mixt inhibitors). This method has a random aspect to it due to the difficulty to predict the diffusion of molecules within the porous network of the concrete. Some concretes do not allow the penetration of inhibitors.

[0006] Cathodic protection consists in creating an anode by placing a metal which is not easily corroded close to the armatures and by leaving a certain thickness of concrete between this metal and the armatures. A current generator is turned on with its positive terminal connected to the anode and its negative terminal connected to the armatures, so as to have a current greater than the corrosion current of the armatures circulate in the concrete. The armatures then act as a cathode in the electrolytic system.

[0007] The current applied to the system is adjustable through the generator according to what is needed. Typically, the currents are adjusted between 2 mA and 20 mA per square meter of armature.

[0008] The cathodic galvanic protection is based on a principle similar to that of cathodic protection, but the supplied current is obtained by the corrosion of the anode which is itself connected to the armatures. Such an anode is referred to as a sacrificial anode. The anodes are made of a metal which is easily oxidized such as zinc, aluminum, magnesium or alloys thereof. The system functions as a battery. The quantity of current delivered by such a system depends on the surfaces of the anode and their composition. The delivered current is limited by the corrosion speed of the sacrificial anodes, their composition and their number.

[0009] The lack of a generator and of a system to regulate the quantities of current is an advantage of the cathodic galvanic protection. However the current generated by the corrosion of the sacrificial anodes remains low and limits the applications of the system. In general, they are below 2 mA per square meter of armature after coupling with the steel has been set. This value is often considered to be insufficient for the protection of armatures exhibiting corroding pits.

[0010] Given that the quantity of galvanic current cannot be increased, a solution consists in reducing the rates of chlorides in the vicinity of the steel to suppress or reduce the effects of corroding spots.

[0011] A known method consists in applying, onto the surface of the concrete, a metallic anode which is embedded in a fibrous matrix impregnated with an electrolyte to ensure electric continuity between the anode and the concrete. The positive terminal of a generator is connected to the anode and the negative terminal to the armatures to apply a current having a high intensity (approximately 1 A/m² of armature) during about 200 hours. The negative ions Cl⁻ are then attracted to the positive polarity of the anode and migrate to the exterior to concentrate around the anode. At the end of the treatment, the anode and the matrix which is impregnated with electrolyte are removed with the chloride ions extracted. The steel armatures are then in a medium which has been rid of aggressive ions, and can then be protected from then on by a galvanic protection whose current is sufficient for a chlorine-free medium.

[0012] Such chloride extraction methods are costly and lengthy. Therefore, they are

not used in this context.

[0013] The patent applications WO 2005/106076 A1 and WO 2006/097770 A2 disclose an intermediary solution which allows to drive the Cl^- ions away from the armatures in a galvanic protection system. The method uses definitive sacrificial anodes located in the concrete so as to, firstly, apply a forced current of a quantity of 50 kilocoulombs (kC) via a generator. This current drives the Cl^- ions away from the armatures by concentrating them around the anode. The generator can then be turned off and the sacrificial anodes can be connected to the armatures. The objective to use a low galvanic current to protect steel from corrosion in a dechlorinated medium is obtained. The remaining chlorides and those likely to enter at a later time will keep on concentrating around the anode during the operating time of the galvanic system. But a negative secondary effect is that the current applied in the first phase accelerates the corrosion of the anode which quickly loses weight and therefore reduces the energy reserve required to maintain the galvanic protection system over time. This loss must be compensated for by extra starting weight for the anode.

[0014] There is therefore a need to improve the galvanic protection techniques in chlorinated environments. In particular, it is desired to obtain a technique which allows to drive the chlorides ions away from the steel armatures without consuming the matter of the sacrificial anodes and/or to increase the pH value in the vicinity of the steels so as to reduce the Cl^-/OH^- ratio (re-alkalize).

[0015] A method for galvanic protection of a concrete structure having metallic armatures is disclosed. The method comprises:

- boring holes in the structure;
- inserting a decontamination electrode and an electrolyte into at least one of the holes;
- electrically connecting a negative terminal of a current source to the armatures and a positive terminal of the current source to each decontamination electrode;
- activating the current source;

- removing the electrolyte and each decontamination electrode;
- arranging and sealing sacrificial anodes in the holes bored in the structure; and
- electrically connecting the sacrificial anodes to the armatures.

[0016] A decontamination phase is carried out before placing the sacrificial anodes. In this decontamination phase, the chloride ions are drawn to the holes where the decontamination electrodes and the electrolyte are located. After the activation of the current source during a long enough time, the decontamination electrodes are removed and so is the electrolyte, which evacuates the majority of the chloride ions out of the structure. Then, the sacrificial anodes are installed and sealed in the holes to ensure a galvanic protection in an environment which holds little chlorine.

[0017] The decontamination phase is carried with a very low additional cost because it relies on holes already made to receive the sacrificial anodes.

[0018] Moreover, by using anode-tools as decontamination electrodes, the mass of the final anodes which will be sealed to ensure the galvanic protection is not consumed. The anode-tools can be used again at some other location of the work, or on another site.

[0019] The decontamination electrode is advantageously made of stainless material, for instance metallic (titanium, stainless steel), or of carbon. It has a relatively important exterior surface for the conduction of current, which can be obtained by forming it as a tube or a spirally wound wire.

[0020] The electrolyte is a material chosen to be retained inside the holes then removed in a simple manner by applying a water stream or compressed air jet or sucked. It is typically in the form of an electrolytic gel whose consistency makes it possible to have the electrolyte maintained by itself in the holes whose diameter does not exceed 25 mm, typically. For other forms of anodes, the diameter of the hole can be increased or decreased.

[0021] The depth of the holes generally corresponds to the depth required to house and correctly set up the final anodes relative to the surface, but it is also possible, to

extract chloride ions more deeply during the step of forced current to make holes having a greater depth which will be, after removal of the gel and cleansing, filled with a hydraulic mortar at the time of the sealing of the galvanic electrodes.

[0022] Other features and advantages of the invention will become apparent from the following description of a non-limiting exemplary embodiment, with reference to the accompanying drawings in which:

- figure 1 is a perspective view of a part of the reinforced concrete structure to which the invention may be applied;
- figures 2 and 3 are other perspective views of the structure part shown in figure 1, at two steps of a decontamination phase;
- figure 4 is a perspective diagram illustrating the introduction of a sacrificial electrode for galvanic protection into a hole bored in the structure part of figures 1-3; and
- figure 5 is another perspective view showing diagrammatically the galvanic protection system installed on the structure part.

[0023] Galvanic protection of the armatures of reinforced concrete is generally obtained by sealing, into holes bored in the concrete, small bodies of easily corrodible metals, such as zinc alloys for example, connected together by an insulated wire and then connected to the armatures of the concrete in one or several points. The sacrificial anodes thus formed become corroded and generate metallic particles in the form of ions. The electrons released by the anodic reaction are distributed to the armatures by the wire connecting them. The current returns through the concrete which acts as an electrolyte.

[0024] The method proposed here uses the holes 15 bored in the concrete 11 (figure 1), provided with a view of sealing the alloy bodies forming galvanic anodes, to perform a prior processing by a forced current so as to extract chloride ions and re-alkalinize the concrete 11 around the armatures 12.

[0025] To implement the galvanic protection technique, holes 15 are bored through the reinforced concrete structure 10, with precautions to avoid hitting the metallic armatures 12. The holes 15 drilled in the structure are arranged so as to have an overlap between the active ranges of the sacrificial electrodes that they will accommodate, in order to cover the area of the armatures to be protected. Typically, in the galvanic protection technique, each sacrificial electrode has an active range of the order of 20 to 30 cm.

[0026] In the method according to the invention, before inserting the sacrificial electrodes into the holes 15, a prior decontamination phase is performed by means of electrodes 16 introduced into the holes 15 (figure 2).

[0027] The decontamination electrodes 16 are preferably made of a stainless material or a weakly corrodible material. In particular, they may be made of titanium, or else of stainless steel. Nonmetallic materials, such as carbon, may also be used.

[0028] In the embodiment illustrated by figure 2, the decontamination electrodes 16 are in the form of a spirally wound metallic wire. Other geometries are possible. In particular, a tube shape is appropriate for the decontamination electrodes 16.

[0029] Each decontamination electrode 16 has an extension consisting of a wire 17 which is also made of stainless material. In the example shown, the electrode 16 is made of a titanium wire wound in the part dipped into the hole 15 and extended to form a rod 17 outside the hole 15.

[0030] The electrodes 16 are introduced into the holes 15 with an electrolytic agent, preferably in the form of a gel. In practice, the holes 15 may be first filled with electrolytic gel which, due to its gelified consistency, is self-maintained inside the holes. The decontamination electrodes 16 are then introduced therein, so as to occupy the whole inner space of the holes 15 with the electrolytic gel.

[0031] The electrolytic gel may be essentially made of a water retention agent and a

base, such as soda lye or the like. For example, for a gel containing 400 g of water, 50 g of sodium hydroxide (NaOH) at 30 % and 40 g of S35-type methylcellulose may be added. With the same proportions, NaOH may be replaced by potassium carbonate (K_2CO_3) to increase the pH in the immediate vicinity of the armatures.

[0032] After introducing the electrolytic gel and the electrodes 16 into the holes 15, the electrodes 16 are electrically connected to each other and to the positive terminal of a current source 18 (figure 3). Regarding the negative terminal of the current source 18, it is electrically connected to the array of metallic armatures 12 of the reinforced concrete structure 10.

[0033] After installing and connecting the decontamination electrodes 16, the decontamination phase comprises activating the current source 18 to apply a current which, at the end of the decontamination phase, may represent, e.g., an integrated charge of 50 kC per m^2 of armatures, that value being non-limiting. The current supplied by the source 18 may be in a range of 0.5 to 1 A per m^2 of armatures contacting the concrete, which gives rise, depending on the surface of the armatures to be protected, to an activation time of the source 18 of the order of a few tens of hours.

[0034] The wire 17 is used to electrically connect the decontamination electrodes 16 to the positive terminal of the current source. Its constitution as an stainless material, on at least part of its length on the side of the decontamination electrode, prevents the electrodes 16 from degrading when being used.

[0035] The current source 18 is a battery or a DC power supply connected to the mains. It is activated to supply a DC current with intensity in a range of 0.5 to 1 A per square meter of armatures.

[0036] In the example shown in figure 3, the electrodes 16 are installed together in the structure 10 to perform the decontamination phase. It will be understood that, depending on the hardware and time available, another option is to introduce and activate successively one electrode 16 or a group of electrodes 16 to decontaminate in

turn several regions of the structure.

[0037] At the end of the decontamination phase, the electrodes 16 are removed from the holes 15, as well as the electrolytic gel which then contains a certain amount of chloride ions which have migrated from the concrete body 11.

[0038] To remove the gel from the holes 15, a stream of water or a compressed air jet is applied, or the gel is sucked.

[0039] The holes 15 are then released and the sacrificial anodes 20 can be introduced therein. By way of illustration, the sacrificial anodes 20 may have a shape as shown in figure 4. In that example, the sacrificial anodes 20 are in the form of a profile having a star-shaped cross-section, so as to provide a relatively important contact area with the mortar 21 which will be used to seal them in the holes 15.

[0040] The sacrificial anodes 20 may be made of any material known for its use in the galvanic protection techniques, i.e. an easily corrodible metal. Zinc or a zinc alloy is a preferred material for the sacrificial anodes 20.

[0041] After introducing the sacrificial anodes 20 into the holes 15 bored in the concrete structure 10, those holes 15 are filled with a sealing mortar 21 (figure 5). Each sacrificial anode has a conducting connection rod 22 which protrudes out of the sealing mortar 21. Those connection rods 22 are electrically connected to each other as well as to the array of metallic armatures of the concrete, as shown in figure 5.

[0042] The installation of the galvanic protection system is then finished. During the future life of the structure, the corrosion-generating electrolytic phenomena cause consumption of the sacrificial anodes 20 rather than corrosion of the metallic armatures 12 of the reinforced concrete structure 10.

[0043] The proposed method enables low-cost extraction of chloride ions since it uses the holes that are already bored. The chloride ions are drained out of the structure

by drawing them through the holes rather than to the surface. The migration time of the ions can thus be reduced.

[0044] Employing reusable anode tools makes it possible not to damage the definitive anode bodies that will be sealed after the extraction and re-alkalization processing.

[0045] The method makes it possible, if desired, to carry on with the processing until the chloride ions are completely extracted. By using anode tools which are not consumed, it is not limited to application of a specific charge.

[0046] The embodiments described or mentioned above are illustrations of the present invention. Various changes can be made to them without departing from the scope of the invention as set forth in the appended claims.

CLAIMS

1. A method for galvanic protection of a concrete structure having metallic armatures (12), the method comprising:

- boring holes (15) in the structure;
- inserting a decontamination electrode (16) and an electrolyte into at least one of the holes;
- electrically connecting a negative terminal of a current source (18) to the armatures and a positive terminal of the current source to each decontamination electrode;
- activating the current source;
- removing the electrolyte and each decontamination electrode;
- arranging and sealing sacrificial anodes in the holes bored in the structure; and
- electrically connecting the sacrificial anodes to the armatures.

2. The method of claim 1, wherein the decontamination electrode (16) is made of a stainless material, in particular titanium, of stainless steel or of carbon.

3. The method according to any one of the preceding claims, wherein the decontamination electrode (16) is formed as a tube or spirally wound wire.

4. The method according to any one of the preceding claims, wherein the decontamination electrode (16) is electrically connected to the positive terminal of the current source (18) by a wire (17) made of stainless material, in particular titanium, on at least part of its length on the side of the decontamination electrode.

5. The method according to any one of the preceding claims, wherein the electrolyte is removed from each hole (15) by applying a stream of water or air.

6. The method according to any one of the preceding claims, wherein the electrolyte is in the form of a gel.
7. The method according to claim 6, wherein the electrolyte is a mixture comprising water, a gelifying agent or water retainer, such as methylcellulose, and a base.
8. The method according to claim 7, wherein the base is sodium hydroxide.
9. The method according to claim 7, wherein the base is potassium carbonate to re-alkalinize the concrete around the armatures (12).
10. The method according to any one of the preceding claims, wherein the current source (18) comprises a battery or DC power supply connected to the mains, activated to supply current in a range of 0.5 to 1 A per square meter of armatures.
11. The method according to any one of the preceding claims, wherein the sacrificial anodes (20) are zinc-based.
12. The method according to any one of the preceding claims, wherein the decontamination electrode (16) is a tool used several times.
13. The method according to any one of the preceding claims, wherein the holes (15) have a depth greater than a depth required for inserting the sacrificial anodes (20).