The use of electrical impedance spectroscopy to detect cracks on the surface of concrete is known from literature (Pour-Ghaz et al., Cement & Concrete Composites (2011) 33: 116–123; and Kang et al., Appl. Sci. (2018), 8: 2582).

There remains a need for reliable methods for monitoring cracking of coating layers when visual inspection of the coating is inconvenient or costly.

SUMMARY

According to a first aspect of the present invention, there is provided a coated structure with a monitoring system, the coated structure comprising a base having a base surface, a coating system comprising one or more layers of cured coat providing protection against surface degradation and being joined to the base surface in a base interface and extending in a thickness direction to an outer coating surface, at least one electrode made from a conductive material embedded in the coating system, and the monitoring system being configured to generate an input signal in the at least one electrode and to read an output signal from the at least one electrode, and from the output signal, to determine cracking of the one or more layers of cured coat, wherein the coating system comprises at least two layers of cured coat joined in a coating interface and forming an adhesive inter coating bond strength, and wherein at least one of the at least one electrode is located in the coating interface and forms an adhesive electrode bond strength to both layers of cured coat, and wherein the adhesive electrode bond strength is higher or equivalent to the coating bond strength between the at least two layers of cured coat.

According to a second aspect of the present invention, there is provided a method of detecting cracking in a cured coat covering a surface of a base, the method comprising:

- embedding at least one electrode in a cured coat and/or between one or more layers of cured coat;
- generating an input signal in the at least one electrode; and
- using a monitoring system to read an output signal from the at least one electrode and based thereon to determine cracking of the cured coat,

wherein the at least one electrode is designed to break essentially simultaneously with said one or more layers cured coat during elongation of the coated structure.

According to a third aspect of the present invention, there is provided a method of detecting cracking in a cured coat covering a surface of a base, the method comprising:

- embedding at least one electrode in a cured coat and/or between one or more layers of cured coat;
- generating an input signal in the at least one electrode; and
- using a monitoring system to read an output signal from the at least one electrode and based thereon to determine cracking of the cured coat,

wherein the at least one electrode is designed to break at the earliest simultaneously with said one or more layers cured coat during elongation of the coated structure, wherein the coating system comprises at least two layers of cured coat joined in a coating interface and forming an adhesive inter coating bond strength, and wherein at least one of the at least one electrode is located in the

coating interface and forms an adhesive electrode bond strength to both layers of cured coat, and wherein the adhesive electrode bond strength is higher or equivalent to the coating bond strength between the at least two layers of cured coat.

According to a fourth aspect of the present invention, there is provided a coating system for protecting a base, the coating system comprising one or more layers of cured coat, wherein an electrode is embedded in at least one of said one or more layers of cured coat or between at least two or more layers of cured coat, wherein the cured coat bonded to the electrode exhibit a first elongation at break, and the electrode exhibit a second elongation at break, wherein the first elongation at break is at most equal to the second elongation at break such that the electrode is configured to break at the earliest simultaneously with the cured coat during elongation of the coated structure, wherein the coating system comprises at least two layers of cured coat joined in a coating interface and forming an adhesive inter coating bond strength, and wherein at least one of the at least one electrode is located in the coating interface and forms an adhesive electrode bond strength to both layers of cured coat, and wherein the adhesive electrode bond strength is higher or equivalent to the coating bond strength between the at least two layers of cured coat.

According to a fifth aspect of the present invention, there is provided a coated structure with a monitoring system, the coated structure comprising a base having a base surface, a coating system comprising one or more layers of cured coat providing protection against surface degradation and being joined to the base surface in a base interface and extending in a thickness direction to an outer coating surface, at least one electrode made from a conductive material embedded in the coating system, and the monitoring system being configured to generate an input signal in the at least one electrode and to read an output signal from the at least one electrode, and from the output signal, to determine cracking of the one or more layers of cured coat, wherein the cured coat has a temperature expansion which is lower than the elongation at break of the electrode.

~~It is an object~~ Embodiments of the present invention seek to improve the ability to monitor a coated structure and particularly to identify cracking in one or more layers of a cured coating system.

According to ~~these and other objects, the disclosure in a~~ the first ~~aspect provides~~ example, there is disclosed a coated structure with a monitoring system configured to exchange electrical signals with the electrode and determine cracking from the signals.

Herein, the term “embedded” means that the at least one electrode is bonded completely to the coating system. “Completely bonded means that opposite inner and outer surface portions of the electrode are bonded to the coating system and both opposite surfaces of the electrically conductive material is thereby in direct contact with and adhered to the coating. This makes the electrode behave like being part of the coating system. In that way it is ensured that cracking of one or more of the one or more layers of cured coat at a position of the electrode also amends or breaks the electrode and that increases the ability to identify cracking of the cured coat.

When used herein, the term “coated structure” is a structure comprising a base and a coating system applied on the surface of the base. The coating system may comprise one or more layers of

cured coat, e.g. a first layer of cured coat and a second layer of cured coat obtained by application of identical and/or different coating compositions. Each layer comprises opposite inner and outer surfaces, the inner surfaces being joined in a coating system interface. The outer surface of the first layer may e.g. be joined to the base in the base interface.

The coated structure comprises at least one electrode embedded in the coating system, i.e. in a layer of cured coat or between more layers of cured coats. The monitoring system is configured for determining cracking based on signals in the at least one electrode, and it may particularly comprise a computer system.

In one embodiment the electrode may be embedded in (inside) a single layer coat meaning embedment in a coating composition in which no coating layer interface can be identified, e.g. a coating obtained by two applications without letting the first application cure completely before applying an electrode and the next layer, i.e. wet on wet application. The coating system then comprises at least one layer of cured coat obtained by at least two passes, i.e. applications of the same coating composition wherein one or more electrodes are embedded in between the at least two applications. In such an embodiment, the electrode has been arranged on top of one or more "first" applications without allowing the coating obtained by the first applications to cure and

The coating system may comprise at least two electrodes, particularly two embedded electrodes. Two electrodes enable capacitance measurement and use of EIS. Decrease of active surface area of the electrode due to breaking of conductors as crack propagates through the coating and conductor would be seen as decrease of capacitance which, similar as in resistance measurements, will be considered as an indication of cracking in the coating system. Alternatively, or additionally, if the cured coat cracks, the distance between the at least two electrodes may change, and that distance change can change the capacitance.

Capacitance-based or EIS-based determining of cracking may be based on an AC signal frequency e.g. measured in the range of frequencies from 1kHz to 100kHz.

When at least two electrodes are used, the electrodes are spatially separated. The term “spatially separated” means that the electrodes are not in direct electrically conductive contact with each other, since they are separated e.g. by air, cured coat, or other dielectric matter.

In a second ~~aspect~~ example, ~~the disclosure provides~~ there is disclosed a method of detecting cracking in a cured coat covering a surface of a base. The method comprises:

- embedding at least one electrode in a cured coat and/or between one or more layers of cured coat;
- generating an input signal in the at least one electrode; and
- using a monitoring system to read an output signal from the at least one electrode and based thereon to determine cracking of the cured coat.

The at least one electrode is designed to break at the earliest simultaneously with said one or more layers of cured coat during elongation of the coated structure.

Cracking may be determined by determining an increased resistance caused by at least partial destruction of the at least one electrode or determined by determining a changed capacitance caused by destruction of the at least one electrode and/or determined by EIS. Resistance based sensing may use an AC or a DC signal whereas the capacitance and EIS based sensing may use an AC signal.

The method may include any steps implicit in view of the coated structure according to the first ~~aspect~~ example of the disclosure.

In a third ~~aspect~~ example, ~~the disclosure provides~~ there is disclosed a coating system for protecting a structure with a base. The coating system comprising one or more layers of cured coat, wherein an electrode is embedded in at least one of said one or more layers of cured coat and/or between two or more layers of cured coat, wherein the cured coat bonded to the electrode exhibits a first elongation at break, and the electrode exhibit a second elongation at break, wherein the first elongation at break is at most equal to the second elongation at break such that the electrode is configured to break at the earliest simultaneously with the cured coat during elongation of the coated structure.

The coating system may comprise two or more layers of cured coat, wherein

a) an electrode is embedded in at least one of the two or more layers of cured coat, wherein the cured coat in which the electrode is embedded exhibits a third elongation at break, and the electrode embedded in the at least one of the two or more layers of cured coat exhibits a fourth elongation at break, wherein the third and fourth elongation at break are essentially equal such that the electrode embedded in the at least one of the two or more layers of cured coat is configured to break essentially simultaneously with or at the earliest simultaneously with the cured coat during elongation of the coated structure.

and/or

b) an electrode is embedded between at least two of the two or more layers of cured coat, wherein at least one of the two or more layers of cured coat exhibits a fifth elongation at break, and the electrode embedded between at least two of the two or more layers of cured coat exhibits a sixth elongation at break, wherein the fifth and sixth elongation at break are essentially equal such that the electrode embedded between at least two of the two or more layers of cured coat is configured to break essentially simultaneously with or at the earliest simultaneously with at least one of the cured coat during elongation of the coated structure.

The coating system may comprise a plurality of different layers of cured coat and a plurality of different types of electrodes, each layer of cured coat having an associated type of electrode such that the associated electrode when embedded in or between the one or more layers of cured coat breaks at the earliest simultaneously with the cured coat during elongation of the coated structure.

The coating system may include any features implicit in view of the coated structure according to the first ~~aspect~~ example of the disclosure or in view of the method according to the second ~~aspect~~ example of the disclosure.

In a fourth example, ~~aspect, the disclosure provides~~ there is disclosed a monitoring system for a coated structure. The monitoring system comprises at least one electrode configured to be embedded in a coating system comprising one or more layers of cured coat covering a base, and a monitoring system configured to generate an input signal in the at least one electrode and to read an output signal from the at least one electrode, and from the output signal, to determine cracking of the cured coat, wherein the at least one electrode is designed to break at the earliest when elongated 10 pct.

The monitoring system may include any features implicit in view of the coated structure according to the first ~~aspect~~ example of the disclosure, in view of the method according to the second ~~aspect~~ example of the disclosure, or in view of the coating system according to the third ~~aspect~~ example of the disclosure.

LIST OF DRAWINGS

In the following, embodiments will be described in further details with reference to the drawing in which:

CLAIMS

1. A coated structure with a monitoring system ~~(1)~~, the coated structure comprising a base ~~(2)~~ having a base surface ~~(3)~~, a coating system comprising one or more layers of cured coat ~~(4)~~ providing protection against surface degradation and being joined to the base surface in a base interface ~~(5)~~ and extending in a thickness direction ~~(6)~~ to an outer coating surface ~~(7)~~, at least one electrode ~~(8, 9, 10, 11)~~ made from a conductive material embedded in the coating system, and the monitoring system being configured to generate an input signal in the at least one electrode and to read an output signal from the at least one electrode, and from the output signal, to determine cracking of the one or more layers of cured coat, wherein the coating system comprises at least two layers of cured coat joined in a coating interface and forming an adhesive inter coating bond strength, and wherein at least one of the at least one electrode is located in the coating interface and forms an adhesive electrode bond strength to both layers of cured coat, and wherein the adhesive electrode bond strength is higher or equivalent to the coating bond strength between the at least two layers of cured coat.

2. The coated structure according to claim 1, wherein the coating system comprises at least one layer of cured coat, wherein said cured coat has been obtained by at least two applications of the same coating composition wherein one or more electrodes are embedded in between the at least two applications of the same coating composition.

3. The coating structure according to any of the preceding claims, wherein the adhesive electrode bond strength is lower or equivalent to a base bond strength between the base and the cured coat closest to the base.

4. The coated structure according to any of the preceding claims, wherein the at least two layers of cured coat are obtained from the same coating composition.

5. The coated structure according to any of the preceding claims, wherein the at least two layers of cured coat are obtained from different coating compositions.

6. The coated structure according to any of the preceding claims, wherein the cured coat bonded to the electrode exhibits a first elongation at break, and the electrode exhibits a second elongation at break, wherein the first and second elongation at break are essentially equal such that the electrode is configured to break essentially simultaneously with the cured coat during elongation of the base ~~(2)~~.

7. The coated structure according to any of the preceding claims, wherein the cured coat bonded to the electrode exhibits a first elongation at break, and the electrode exhibits a second elongation at break, wherein the first elongation at break is at most in the order of the second elongation at break such that the electrode is configured to break at the earliest simultaneously with the cured coat during elongation of the base ~~(2)~~.

8. The coated structure according to any of the preceding claims, wherein the cured coat has a temperature expansion which is lower than the elongation at break of the electrode.

9. The coated structure according to any of the preceding claims, wherein the conductive material has a thermal expansion coefficient being essentially equal to the thermal expansion coefficient of at least one of said one or more layers of cured coat.

10. The coated structure according to any of the preceding claims, wherein the conductive material comprises a conductive flexible polymer or polymer blend such as for example poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS), Polypyrrole (PPy), polyphenylene vinylene (PPV), polyacetylene, or Polyaniline (PANI).

11. The coated structure according to any of claims 1-9, wherein the conductive material comprises a non-conductive flexible polymer or polymer blend comprising a conductive dopant.

12. The coated structure according to claim 11, wherein the dopant comprises a metal such as silver, copper, aluminium, iron or zinc.

13. The coated structure according to any of claims 11-12, wherein the dopant comprises elements from the carbon family such as graphene, graphite, or carbon nanotubes.

14. The coated structure according to any of the preceding claims, wherein one of the at least one electrode forms a plurality of conductors extending individually between two connectors, and wherein a total resistance between the connectors is calculated based on a contribution from each conductor.

15. The coated structure according to any of the preceding claims, wherein the at least one electrode is bonded completely to the cured coat.

16. A method of detecting cracking in a cured coat covering a surface of a base, the method comprising:

- embedding at least one electrode in a cured coat and/or between one or more layers of cured coat;
- generating an input signal in the at least one electrode; and
- using a monitoring system to read an output signal from the at least one electrode and based thereon to determine cracking of the cured coat,

wherein the at least one electrode is designed to break essentially simultaneously with said one or more layers cured coat during elongation of the coated structure.

17. A method of detecting cracking in a cured coat covering a surface of a base, the method comprising:

- embedding at least one electrode in a cured coat and/or between one or more layers of cured coat;

- generating an input signal in the at least one electrode; and
- using a monitoring system to read an output signal from the at least one electrode and based thereon to determine cracking of the cured coat,

wherein the at least one electrode is designed to break at the earliest simultaneously with said one or more layers cured coat during elongation of the coated structure, wherein the coating system comprises at least two layers of cured coat joined in a coating interface and forming an adhesive inter coating bond strength, and wherein at least one of the at least one electrode is located in the coating interface and forms an adhesive electrode bond strength to both layers of cured coat, and wherein the adhesive electrode bond strength is higher or equivalent to the coating bond strength between the at least two layers of cured coat.

18. The method according to claim 16 or 17, wherein cracking is determined by determining an increased resistance caused by at least partial destruction of the at least one electrode.

19. The method according to any of claims 16-18, wherein said coating system comprises at least two electrodes, wherein cracking is determined by determining a changed capacitance between the at least two electrodes.

20. The method according to any of claims 16-19, wherein cracking is determined by EIS.

21. A coating system for protecting a base, the coating system comprising one or more layers of cured coat, wherein an electrode is embedded in at least one of said one or more layers of cured coat or between at least two or more layers of cured coat, wherein the cured coat bonded to the electrode exhibit a first elongation at break, and the electrode exhibit a second elongation at break, wherein the first elongation at break is at most equal to the second elongation at break such that the electrode is configured to break at the earliest simultaneously with the cured coat during elongation of the coated structure, wherein the coating system comprises at least two layers of cured coat joined in a coating interface and forming an adhesive inter coating bond strength, and wherein at least one of the at least one electrode is located in the coating interface and forms an adhesive electrode bond strength to both layers of cured coat, and wherein the adhesive electrode bond strength is higher or equivalent to the coating bond strength between the at least two layers of cured coat.

22. The coating system according to any of claims 21-, wherein said coating system comprises two or more layers of cured coat, wherein

a) an electrode is embedded in at least one of the two or more layers of cured coat, wherein the cured coat in which the electrode is embedded exhibits a third elongation at break, and the electrode embedded in the at least one of the two or more layers of cured coat exhibits a fourth elongation at break, wherein the third and fourth elongation at break are essentially equal such that the electrode embedded in the at least one of the two or more layers of cured coat is configured to break essentially simultaneously with or at the earliest simultaneously with the cured coat during elongation of the coated structure.

and/or

b) an electrode is embedded between at least two of the two or more layers of cured coat, wherein at least one of the two or more layers of cured coat exhibits a fifth elongation at break, and the electrode embedded between at least two of the two or more layers of cured coat exhibits a sixth elongation at break, wherein the fifth and sixth elongation at break are essentially equal such that the electrode embedded between at least two of the two or more layers of cured coat is configured to break essentially simultaneously with or at the earliest simultaneously with at least one of the cured coat during elongation of the coated structure.

23. The coating system according to any of claims 21-22, comprising a plurality of different layers of cured coat and a plurality of different types of electrodes, each layer of cured coat having an associated type of electrode such that the associated electrode when embedded in or between the one or more layers of cured coat breaks essentially simultaneously with or at the earliest simultaneously with the cured coat during elongation of the coated structure.

24. A coated structure with a monitoring system ~~(1)~~, the coated structure comprising a base ~~(2)~~ having a base surface ~~(3)~~, a coating system comprising one or more layers of cured coat ~~(4)~~ providing protection against surface degradation and being joined to the base surface in a base interface ~~(5)~~ and extending in a thickness direction ~~(6)~~ to an outer coating surface ~~(7)~~, at least one electrode ~~(8, 9, 10, 11)~~ made from a conductive material embedded in the coating system, and the monitoring system being configured to generate an input signal in the at least one electrode and to read an output signal from the at least one electrode, and from the output signal, to determine cracking of the one or more layers of cured coat, wherein the cured coat has a temperature expansion which is lower than the elongation at break of the electrode.