Corrosion Surveys on Reinforced Concrete Structures

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Signs of distress on concrete surfaces are often indicators for invisible noxious processes that are affecting larger areas of the concrete. Such visible defects give reason to diligent investigation.

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Corrosion of steel in concrete is a wide spread problem, as described in issue no. 1 of our Fortytwo-Infoletter. It affects structures exposed to seawater or salty ground water, de-icing salt, chlorine gas evaporating or leaking from swimming pools and fountains, chemicals used in production and many more. Even the CO_2 in the atmosphere affects the concrete and can cause reinforcement corrosion by means of the so-called carbonation.

A number of methods are available to prevent or reduce reinforcement corrosion. These must be selected and applied carefully, since failing to do so may cause even more damage to the reinforcement. The best basis for correct selection and application of protective measures is always a comprehensive building investigation by qualified corrosion specialists.

Most Methods are non-destructive

The methods used in corrosion surveys are mostly non-destructive and can reveal corrosion in suspected areas even if no damage is visible. A corrosion survey can detect reinforcement corrosion in an early stage and help prevent further deterioration that would require major repair work or demolition of the structure.

Advanced methods used in corrosion surveys are based on the detection and measuring of electro-chemical

Method	Non-destructive	Semi-destructive	Full surface	Spot	Standard	Advanced
Visual check	•		•		•	
Delamination check (acoustic)	•		•		•	
Corrosion potentials	•		•		•	
Concrete resistance	•		•		•	
Concrete cover	•		•		•	
Chloride profiles		•		•	•	
Alkalinity		•		•	•	
Moisture content		•		•	•	
Linear polarisation resistance	•			•		•
Galvanostatic pulse measurement	•			•		•
Tafel measurement	•			•		•

effects that go along with the corrosion reaction. The corroding areas exhibit a displacement of electrical charges on the steel surface. These charges can be detected on the concrete surface. **Adding advanced methods to the testing regime reduces the cost of rehabilitation and protection significantly.**

Fig. 1: Visual inspection (typical defect).

1. Visual Inspection

The visual check can tell already a lot about the condition of the building or structure and about the cause of the defects. Visible defects are recorded on a defects map from where they can be precisely located later. It is useful to also record observations in a photo documentation for future reference and verbally describe them in a defects register. The defects map often reveals causes of defects and is the basis for planning further investigation steps. A visual inspection and mapping of visible defects should always be the first step of a corrosion survey.

Fig. 2: Delamination check.

2. Delamination Check

Closely associated with the corrosion reaction are usually hollow sounding areas on the concrete surface. Once transformed into rust, the steel occupies a greater volume and thus breaks the outer concrete layer. This thin layer of delaminated concrete has acoustic properties that are audibly different from those of sound, solid concrete. The area under suspicion is investigated by dragging instruments across the surface that cause audible vibrations. Defective (hollow) areas can then be identified by the sound that is produced. Hence hollow sound is a strong indicator for reinforcement corrosion. Delaminated areas are recorded on the defects map and in the defects register.
Such - often invisible - defects cannot be protected by preventive measures anymore. The damage has occurred already and the area needs to be repaired conventionally prior to the application of any protection. However, it is important to identify such areas and repair and protect them before the structure as a whole gets damaged beyond repair.

Fig. 3: Recording potentials and resistivity.

3. Corrosion Potentials

Electrical potentials (voltages) caused by the corrosion reaction can be picked up on the surface of the concrete. This is usually done by placing a reference electrode on the concrete surface. A volt-meter then measures the voltage (potential-difference) between the reinforcing steel and the reference electrode. The measured potentials provide information about possible corrosion taking place inside the concrete. The measured voltages are sometimes ambiguous and need to be seen in the context with other measurements. So can, for example, very wet concrete result in potential readings that would indicate corrosion in rather dry concrete, even though no significant corrosion is possible in water saturated concrete. It requires experienced specialists to interpret the results correctly.

4. Concrete Resistance

The electrical resistance of the concrete plays an essential role in the corrosion process. Since corrosion is an electrochemical reaction with exchange of electrical charges within the steel as well as through the concrete, the concrete resistance influences the rate of deterioration.

5. Concrete Cover

The concrete cover (the distance of the outer steel layer from the concrete surface) is protecting the steel from noxious influences. Knowledge of the concrete cover thickness is essential for predicting the service life of a concrete structure. Chlorides and the carbonation reaction (caused by CO_2-ingress) for example penetrate into the concrete usually from the surface and migrate from there towards the reinforcement at a certain speed. From that speed and the remaining distance to the reinforcement, a remaining service life can be roughly estimated.

6. Chloride Profiles

Concrete dust samples are collected from a number of depth intervals using a drilling machine. The samples are analysed for concentration of contained chloride. Chlorides can trigger corrosion if a certain concentration threshold is reached. Since chlorides are migrating in the concrete, chances for future corrosion can be estimated and preventive or corrective measures can be planned.

7. Alkalinity

The usually high alkalinity (pH-value) inside the concrete causes the steel to form a passivation layer, that protects it from corrosion. Several influencing factors, such as CO_2-ingress, can reduce the alkalinity such that the passive layer gets destroyed and the corrosion protection is lost. A rough test can be done on freshly exposed concrete surfaces using indicator liquids like phenolphtalein- or thymolphtalein-solutions. The indicator fluids change their colour at a certain pH-value. The colors indicate the limit between carbonated and uncarbonated areas in the concrete. For more detailed results samples may be analysed in a laboratory and their respective pH-values may be related to the sampling depth.

Fig. 7: Combination probe for potential and resisitivity measurement (System ClTec).

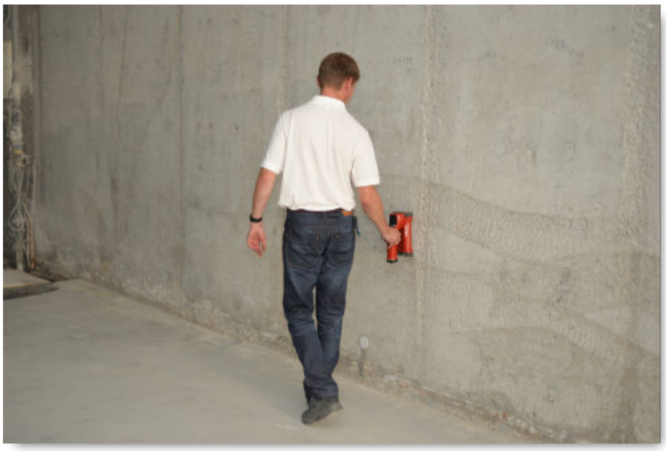

Fig. 4: Measuring concrete cover.

Fig. 5: Collecting drill dust samples.

Fig. 6: Checking carbonation depth on a core sample using an indicator liquid.

8. Moisture Content

The moisture content has an impact on electrical resistance, migration of substances, ingress of gasses (CO_2) and also influences potential readings. High moisture content can generate potentials indicating corrosion without significant corrosion actually taking place. Therefore an understanding of the moisture content can be essential for the correct interpretation of potential readings. The moisture content is usually

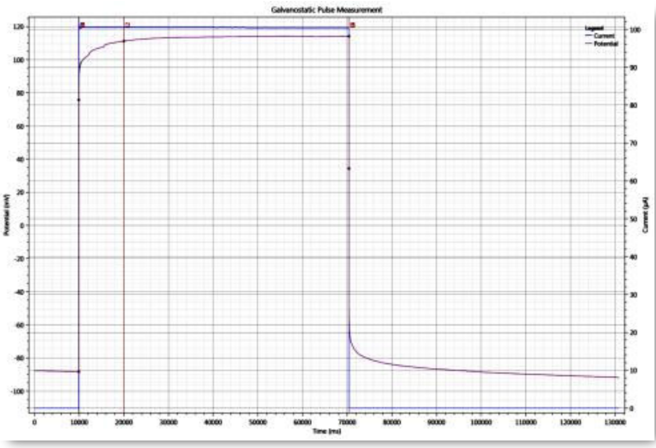

Fig. 8: Galvanostatic pulse measurement.

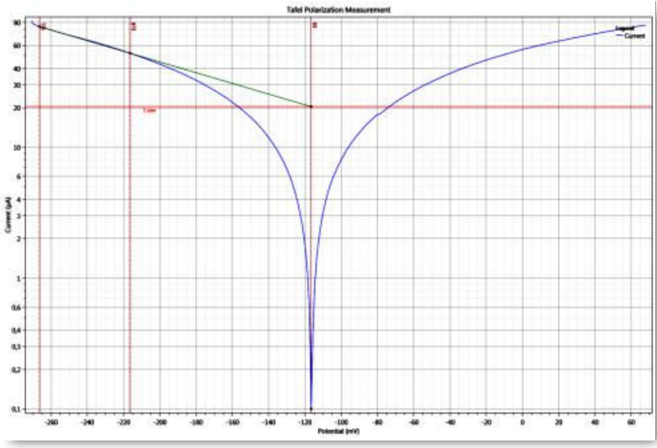

Fig. 9: Tafel polarization measurement.

tested in drill-dust samples which must be sampled carefully and sealed properly to avoid loss of moisture.

9. Linear Polarisation Resistance

The linear polarisation resistance measurement is used to (roughly) estimate the corrosion rate. A known current is forced through the steel-concrete interface and the change in surface potential caused by the current is measured. From this the quantity of steel that is dissolved over a period of time can be calculated. However, especially in case of pitting corrosion, the results are often doubtful. We use this method only for plausibility checks for other methods.

10. Galvanostatic Pulse Measurement

During the galvanostatic pulse test a constant current is impressed into a limited area of reinforced concrete. The current alters the steel potential. From the alteration of the steel potential over time the corrosion specialist can determine whether the steel is in a passivated state (see ‘Alkalinity’ above).

11. Tafel Test

The Tafel polarisation test allows to estimate the corrosion rate more precisely than linear polarisation resistance measurement. In addition to that the effect of a corrosion protection system can be simulated on site to assess the suitability of planned protection methods.

Reliable conclusions

Correct conclusions from a corrosion survey are a pre-requisite for cost efficient, yet reliable corrosion protection. This can be achieved only by combining a variety of measurements and correct inter-pretation of the same by an experienced expert. Adding advanced methods reduces the cost for rehabilitation and protection.

Fig. 10: KMS-probe0 (System CITec) for LPR-, Galvanostatic Pulse- and Tafel-tests.

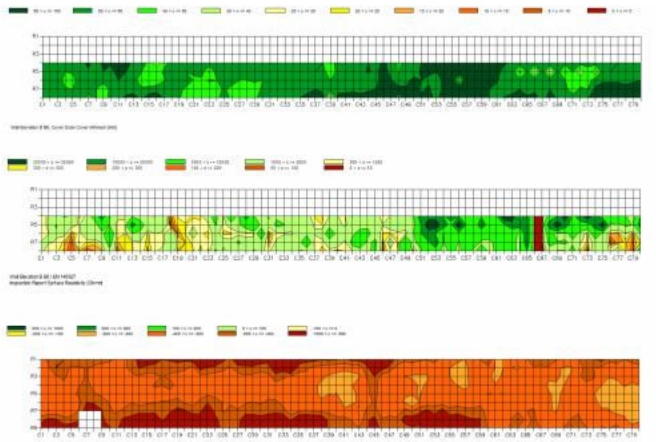

Fig. 11: Rendering measurements in contour plots.