Corrosion Testing of Concrete Structures

Technical Note 27

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OVERVIEW

The following technical note is aimed to provide a concise summary on the most commonly used corrosion testing techniques for reinforced and pre-stressed concrete structures. This document should be used in conjunction with other, well-established publications, some of which are listed at the end of this document, which provide greater detail on the test method and interpretation of the test data.

INTRODUCTION

Over the past 20 years, corrosion testing on concrete structures has been used increasingly for monitoring deterioration as well as for defining the areas in need of repair. While this is a positive change, often the quality and the rationale behind the testing are not sufficiently well defined. When trying to understand the cause of corrosion, it is important to appreciate that the problem is rarely an issue affecting the whole structure uniformly, but often starts as a localised problem. Ascertaining the risk of corrosion cannot be achieved by random chloride sampling and visual/delamination surveys alone; testing needs to be properly planned by competent professionals and tailored to the specific needs of each structure.

The initial cause of corrosion is commonly the result of a number of interrelated variables: changes in the concrete permeability, caused by local differences in composition, compaction and curing; construction errors leading to areas with low concrete cover to reinforcement; and variation in the exposure environment, leading to areas with elevated chloride ion content or high carbonation depth. The first instances of corrosion initiation will often be in areas where permeable concrete, low cover and more severe exposure conditions coincide on a particular element. Also, there is often a delay of several years between embedded steel becoming corrosively active and the development of corrosion that leads to visible damage (and then only provided sufficient moisture is present within the concrete).

Structures can often be subdivided into different exposure categories, such as environmental zones in areas of spray, splash or immersion, and risk zones such as areas subject to leakage. A bridge is a good example, where details such as half joints are often subject to leakage of de-icing salt due to failed movement joints, whereas the middle of the bridge abutment will be sound and dry. Both areas are also influenced by different environmental factors that provide a different corrosion-risk profile. For migratory chlorides in particular, (chloride ions that enter the concrete via external sources) corrosion risk is related to the presence of chlorides in water; half joints, splash zones, tidal zone, drainage etc., all increase the probability of chloride contamination in a particular area and therefore increase risk, as shown below.

FIGURE 1: An example of how leaking drainage can create its own environment for corrosion risk.
The aim of comprehensive corrosion testing should be to understand the exposure variability, ascertain risk and develop a repair and maintenance strategy that provides the best technical and commercial solution for the structure. (The field of structural variability and associated risk are well covered in BRE Digest 444 – Part 2. Corrosion of Steel in Concrete – Investigation and Assessment, 2000).

The most commonly used methods for ascertaining risk are:

1. Delamination and visual surveys
2. Global, open grid half cell potential surveys

The findings of 1 and 2 should be used to select or target representative locations for:

3. Detailed, closer grid half cell potential surveys
4. Screening for chloride and other contamination
5. Testing for depths of carbonation
6. Corrosion rate monitoring
7. Concrete resistivity testing
DELAMINATION AND VISUAL SURVEYS

These methods are the most commonly used techniques for identifying deteriorated and damaged surfaces. However, their use is generally limited to the areas where visual indications of damage are seen, such as cracking, rust staining and concrete spalling/delamination, and examples are given in Figure 2. Sheet delaminations can occur, with no outward, visible, signs of damage, with careful hammer testing required to resolve these details. Furthermore, as explained below, situations do occur where corrosion is taking place with no outward signs of visible corrosion or damage, such as corrosion within post-tensioning ducts, or in areas with high saturation levels. Also, it takes a certain time for corrosively active reinforcement to develop into rust staining, delamination and spalling. Therefore, reliance on delamination and visual surveys alone is unwise.

FIGURE 2: Visual examples of corrosion on concrete structures.

Physical damage can be easily quantified for the structure and used to build a ‘Bill of Quantities’ (BoQ) for tender stage repair work. While a BoQ is essential for pricing any repair scheme, visual surveys alone can underestimate the actual areas needed for repair, because the underlying damage and deterioration is significantly larger than can be seen at the surface; commonly, the area of a slab repair, or the length of a repair such as a beam arris, will turn out to be two or more times greater than the visible damage alone.

Visual inspection can be a much more powerful tool when combined with an understanding of the environmental conditions that impact the structure and the other methods of risk assessment explained below. While this type of testing will not provide any indication of actual risk to currently sound concrete, it does provide significant information as to where other, more scientific methods could be used. This in turn, helps define the global risk of corrosion that cannot be quantified visually. It is also extremely useful to include some breakouts to expose areas of bar to check for corrosion during visual inspections, allowing other tests to be performed as well (see cover meter calibration).
CARBONATION TESTING

Carbonation as outlined in CPA Technical Note 1 is the process whereby atmospheric carbon dioxide (CO$_2$) penetrates into the concrete surface and reduces the protective alkalinity of the concrete cover. The rate of carbonation is heavily dependent upon the strength, permeability and quality of the concrete and the exposure environment, with regularly wetted external concrete carbonating more slowly than internal or sheltered concrete. Once the carbonation front reaches embedded steel, the protective passive film naturally present on steel in concrete is broken down and general corrosion can begin (provided sufficient moisture is present within the concrete), as shown in Figure 3. The depth of carbonation can easily be determined on site using phenolphthalein indicator, sprayed onto a freshly broken concrete sample. This method is outlined in BS EN 14630:2006.

It is vital however that the surfaces of cores and drilled holes are not used for this purpose. Dust from areas of higher alkalinity can mix with the carbonated concrete to give falsely low readings. The best method is to create a freshly broken sample that has been removed via a shearing action or to split a core in two. An example is given in Figure 4 below.

FIGURE 3: The following diagrammatic illustrations of carbonation are taken from the BRE Digest 444 – Part 1.

FIGURE 4: Testing for carbonation on a freshly sheared concrete sample
A number of samples should be taken over the structure to obtain a distribution of carbonation depths and these compared against the cover depths around the structure to find areas at risk. In some cases, elements of similar strength, composition and exposure (e.g. sheltered or exposed to rain, prevailing wind direction, etc.) can be grouped together to obtain average depths of carbonation.

With knowledge of the age of the structure, the carbonation depth can be converted to a carbonation rate, from which an estimation can be made of the increasing risk of corrosion due to carbonation in the future; Figure 5 shows the approximate relationship, predicting that if the carbonation depth is measured as 36mm after 20 years, it will be approximately 50mm after 40 years.

![Figure 5: Approximate prediction of future carbonation](image)
DETERMINING CHLORIDE CONTENT

Chloride contamination of concrete is by far the most significant cause of reinforced concrete corrosion globally. Rapid loss of steel cross sectional area can occur, particularly in bridges and maritime structures. However, there are two main modes of chloride contamination:

1. **Migratory Chlorides** – entering the structure from an external source. This is the most common form of chloride-induced reinforcement corrosion. Most commonly the source is chloride-based de-icing salts and seawater from the marine environment (both airborne spray and contact with saline water), but other sources are possible from industrial processes. When the chloride ion content typically exceeds 0.2-0.4% by mass of cement, the protective film around the bar is destroyed and corrosion cells can form;

2. **Cast In chlorides** – added at the time of mixing. Nominally half of the chloride added at mixing binds harmlessly with the cement, explaining why relatively high chloride contents can be tolerated, but is more or less released back into circulation, potentially to initiate corrosion, when the concrete becomes carbonated. In the UK the main source was calcium chloride, used as a set accelerator during cold spells at dosages often between 1% and 2% by mass of cement (as this was not subjected to stringent quality control much higher levels have been encountered) until it was effectively banned through the amended CP110: 1977 (hence only concrete structures older than 1977 are affected and likely to be found in buildings and dryer internal elements). More recently, sources include brackish mix water (rarely, seawater) or poorly washed marine-sourced aggregates. Contamination of this kind is not always universal as different parts of a structure may have been built during different days or seasons and over a single or multiple years and so have more chloride than others.

The test method for determining chloride levels is covered by BS EN 14629:2007. While the main aim of chloride testing on site should be to determine the level of chloride contamination at the depth of the reinforcement, testing can also provide information as to the most likely mode of entry (Figure 6). This additional information is important as the mode of entry will have an impact upon the overall risk of corrosion. This information must be considered when a risk/repair strategy is developed.

![Figure 6: Typical chloride profiles in concrete.](image-url)
It is important to consider that the risk of corrosion due to chloride contamination is very much dependent upon the mode of contamination (migrating or cast-in), the quality of the concrete and environmental factors such as moisture content. The rate of corrosion will be much more severe for damp external concrete with migrating chloride, than for dry internal beams containing cast-in chloride, which may appear corrosion free. Further, areas that are contaminated with migrating chloride ion may not corrode at all, as these cathodic areas are being protected by corrosion at the anodic areas. This underscores why visual inspection, in isolation, is not a reliable indicator of underlying corrosion activity. Also, due to the anode-cathode mechanism, the level of chloride determined should only be used as a guide (See figure 7) to risk and these results used in conjunction with other tests (e.g. Half-cell potential, resistivity and corrosion rate) to better determine actual risk of corrosion and actions such as repair.

Concrete structures with cast-in chloride may give many decades of service in dry conditions without any signs of corrosion. Initiation may only happen when significant carbonation has occurred in the cover concrete, which will release most of the bound chloride back into the pore solution and initiate corrosion cells. Therefore, commonly used Risk/Concentration guidelines may not be suitable. In general the values in Table 1 are used for the determination of risk.

<table>
<thead>
<tr>
<th>Chloride Content by Weight of Cement %</th>
<th>Risk of Corrosion Uncarbonated concrete (pH &gt;10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.2</td>
<td>Negligible</td>
</tr>
<tr>
<td>0.2 to 0.4</td>
<td>Very Low</td>
</tr>
<tr>
<td>0.4 to 0.8</td>
<td>Low or Moderate</td>
</tr>
<tr>
<td>0.8 to 1.5</td>
<td>High</td>
</tr>
<tr>
<td>&gt;1.5</td>
<td>Extremely High</td>
</tr>
</tbody>
</table>

**TABLE 1: Corrosion Risk from cast-in chlorides in uncarbonated concrete.**

**FIGURE 7:** Risk variability of migratory chlorides in real structures. Taken from BRE Digest 444 Part 2.
It is a common misconception that we can now design out problems of corrosion through better concrete and better designated cover. While there have been improvements in the understanding of the factors affecting durability (e.g. BS 8500), errors can still occur on site that result in areas of poor quality concrete or low cover, which will vary over the surfaces of the structure. It is important therefore that when ascertaining corrosion risk that this inherent variability is fully considered and low cover areas are identified and protected as necessary.

Concrete cover to steel reinforcement is the first line of defence against corrosion. In theory the greater the thickness and quality of the cover, the less likely it will be that corrosion is going to be a problem over the design service life, although too thick a cover can cause other problems (e.g. wide flexural cracking). As shown above, the penetration of chloride ions and carbonation can be established and the speed of attack depends on the environment in which the structure is located. The less cover there is, the faster chloride and carbonation will reach the steel surface. Data on the carbonation depth and chloride content at the bar depth must therefore be related to the actual cover and not the designed cover for the structure under assessment. Only the combination of both gives an estimation of corrosion risk.

The process of carrying out this method is well documented in the references but in principle an electromagnetic cover meter is used to BS 1881-204. There are a number of different systems available including those that estimate the bar diameter as well as depth. This is particularly useful when as-built drawings are not available. Impulse radar can also be used for this purpose. Validation of actual cover by breakout calibration in selected areas is strongly recommended, as certain pozzolans and aggregates contain magnetite, which can affect the cover reading.
HALF-CELL POTENTIAL SURVEYS

All of the methods of testing so far have been concerned with visual deterioration, environmental factors and spot (localised) tests. The biggest problem with chloride corrosion in particular is that it starts unseen within the concrete, setting up corrosion cells where anodic areas actively protect cathodic areas. The benefit of half-cell testing is that it gives a method of determining risk of corrosion activity over a whole structure without the need to break away large areas of concrete to inspect the bar. This is an extremely valuable technique that is now moving away from small individual test areas (that represent less than 1% of a structure) to full investigative surveys.

Concrete with chloride contamination will induce a different (more negative) voltage than steel that is in fresh uncontaminated concrete. The method works on the basis that steel in an electrolyte (concrete) forms a half cell, with a relative potential that can be measured using a high impedance digital voltmeter. This is compared against a reference cell, typically a silver-silver chloride (Ag-AgCl) electrode. The voltage will be more negative in areas that have a higher chance of corrosion activity compared with cathodic (passive) areas. The method is described in detail in two documents: ASTM C876-09 & Concrete Society Technical Report 60.

Typically, a grid is marked on the concrete area to be tested (typically 500mm x 500mm or 1000mm x 1000mm spacing) and readings recorded at the node points. While it can be useful to look at individual readings, often the data is converted into a colour contour map that is easier to interpret when large areas of a structure are tested. Table 2 below provides the general interpretation of the half-cell potential value against risk of corrosion, based on ASTM C876-09. It must be stressed that Table 2 gives a general interpretation of corrosion risk, as it only indicates that conditions at the bar are suitable for corrosion, at the time of measurement, not that corrosion is definitely occurring. Repeat measurements on the same structure may also indicate differing results at differing times of year, e.g. hot, dry summer, compared to warm, wet autumn / spring, compared to cold winter, with significant negative shifts in potentials in warm, wet conditions. Furthermore, for any particular structure, the numerical values of half-cell potential and the corresponding risk may vary, from element to element and need to be interpreted with care: for dry elements, all values may be more positive than shown; for very wet elements the values may be more negative (-500mV is commonly seen), but with saturated concrete, corrosion may not be occurring at all. Therefore it is important to calibrate the readings on the structure and elements under test by breaking out representative areas and inspecting the reinforcing bar for evidence of deterioration and corrosion.

<table>
<thead>
<tr>
<th>Cu-CuSO₄ electrode</th>
<th>Percentage chance of corrosion activity</th>
<th>Ag-AgCl electrode</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; -200 mV</td>
<td>Low - &lt;10% risk of corrosion</td>
<td>&gt; -120 mV</td>
</tr>
<tr>
<td>-200 to -350 mV</td>
<td>Intermediate corrosion risk</td>
<td>-120 to -270 mV</td>
</tr>
<tr>
<td>&lt; -350 mV</td>
<td>High - &gt;90% risk of corrosion</td>
<td>&lt; -270 mV</td>
</tr>
</tbody>
</table>

TABLE 2: Corrosion risk, according to Bungey, based on ASTM C876-09
The following Figure gives an example of half-cell potential data from a live project where de-icing salts have been allowed to soak into the top surface of the car park deck slab.

![Figure 8](image)

**Figure 8:** Typical half-cell potential map, taken over an unwaterproofed car-park deck.

As can be seen in Figure 8, the risk of corrosion over a structure can vary greatly and the method of repair and treatment may not be a universal solution.

It is most useful to take all of the test data and map this onto a single drawing, showing the visual/delamination survey data alongside the half-cell potential data and supported by cover readings, carbonation depths and chloride contents at the bar depth. This enables the user to quantify the areas that are likely to be ‘at risk’ from corrosion which may require intervention measures such as concrete patch-repair, with or without global corrosion protection measures, including coatings, corrosion inhibitors, sacrificial anodes or impressed cathodic protection, or a combination of such measures.

An example of such an approach is given in Figure 9 below.

![Figure 9](image)

**Figure 9:** Overlay of areas of delaminated concrete onto high negative half-cell data.
Providing such detailed information within specifications of work, sent for tender, is a significant advantage. Firstly it enables the problem of corrosion to be quantified, the base level of repair documented and the amount of preventative measures detailed. This means the bidding contractors are all pricing the same work and therefore the owner/engineer can compare like for like. It also allows for far better cost budgeting and ultimately a better technical solution for the needs of the structure.
CORROSION RATE MONITORING

The rate of corrosion of steel in concrete may be measured using the polarisation resistance or linear polarisation technique, commonly abbreviated to LPR. An LPR meter consists of a half-cell, the high impedance digital voltmeter needed to take readings from it and a computer controlled power supply which applies a small current or controlled potential offset to the reinforcing steel being measured. The system is illustrated in Figure 10.

The advantage of the LPR technique over the half-cell is that it measures the actual corrosion current, not just the fact the conditions at the bar are suitable for corrosion. Also, it takes into account the degree of saturation of the concrete, which can prevent corrosion from occurring. However, it is a far slower technique and requires careful alignment of the sensor over a known surface area of steel, taking several minutes to take a reading. LPR Is therefore useful on very wet structures, such as marine conditions, or leaking basements, and as a laboratory tool. The meters are generally set up to give the corrosion rate in micrometres per year (µm/y). Results are generally interpreted as:

- <2 µm/y  Passive condition, no corrosion
- 2 – 10 µm/y  Corrosion damage possible in 10-15 years
- 10 – 100 µm/y  Corrosion damage possible in 2-10 years
- >100 µm/y  Corrosion damage possible in <2 years.

Various factors affect the corrosion rate and its measurement as explained in Concrete Society Technical Report 60.

In some instances, the targeted measurement of corrosion rate may provide useful additional information, e.g. when developing life care plans, using global half-cell potential data to identify specific, representative, locations for test.
RESISTIVITY TESTING

Since corrosion is an electrochemical phenomenon, the electrical resistivity of the concrete cover will affect the corrosion rate of the concrete, as an ionic current (electric current in the form of a flow of charged ions in the pore water) must pass from the anodes to the cathodes for corrosion to occur.

The four probe resistivity meter or Wenner Probe was developed for measuring soil resistivity (based on ASTM G57). Specialised modifications of the Wenner probe are frequently used for measurement of concrete resistivity on site and is fully described in the literature. The measurement can be used to indicate the rate of possible corrosion activity if steel is de-passivated by carbonation or chloride penetration. A typical 4-probe resistivity meter is shown in Figure 10.

Site resistivity measurements are strongly affected by surface wetting (e.g. rain) and internal moisture content of the concrete and as it is difficult to condition site concrete to a constant moisture content, some variation is inevitable. For more controlled measurement cores are taken and then vacuum saturated in the laboratory to establish the lowest (worst case) resistivity. As well as moisture content, the results and interpretation are influenced by the presence, proximity and orientation of reinforcement. More detail is given in Concrete Society Technical Report 60 and Bungey.

An approximate guide to corrosion rate measured by resistivity, assuming the steel is de-passivated and the concrete is moist but not saturated, is given by:

- > 20 kΩ cm. Low Corrosion rate
- 10-20 kΩ cm. Low to moderate corrosion rate
- 5-10 kΩ cm. High corrosion rate
- < 5 kΩ cm. Very High Corrosion rate

In some instances, the targeted measurement of resistivity may provide useful additional information, using global half-cell potential data to identify specific, representative, locations for testing.
CONCLUSIONS

The determination of corrosion risk over a structure is not straightforward. The methods outlined above enable the user to better understand how to assess corrosion risk and therefore make informed decisions about repair strategy based upon a broad base of information. Often, with real structures, any repair scheme is a compromise between the best technical solution and the overall cost to carry out the scheme. As the needs of our aging infrastructure increase, it is important that the decisions put forward are informed and risk is properly quantified and managed. Only through a better understanding of the structure can this be achieved and is the reason why testing is one of the most important elements of any scheme.
The following table provides a list of some of the testing techniques employed and some useful sources of further information:

<table>
<thead>
<tr>
<th>METHOD</th>
<th>STANDARDS OR GUIDANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>VISUAL</td>
<td>The recognition of ASR is discussed in the SHRP manual on ASR (Stark 1991) and in HWYCON 1994. Concrete Bridge Development Group (2002) has a table of 25 examples of cracks and visual defects with photographic examples in an appendix.</td>
</tr>
<tr>
<td>DELAMINATION</td>
<td>ASTM D4580-03 (2003) describes delamination detection in concrete bridge decks using a chain drag, hammers, rotary percussion and the “Delamatect” system. The standard concludes that the chain drag procedure is the most reliable technique. There is also a standard, ASTM D4788 (2003) covering infrared thermography of concrete and asphalt covered concrete bridge decks. This requires a scanner with a minimum thermal resolution of 0.2 degrees Celsius and says that the temperature difference between a delamination or debonded area should be 0.5°C. The standard is for a vehicle mounted system and claims 80 to 90% of delaminations can be found in concrete decks with or without an asphalt overlay.</td>
</tr>
<tr>
<td></td>
<td>ASTM D 6087-05 (2005) covers the use of ground penetrating radar to evaluate asphalt covered concrete bridge decks. It is designed for vehicle mounted or manually driven systems. It claims the system is accurate in detecting delaminations to within ±11.2% according to a precision test on 10 bridge decks in New York, Virginia and Vermont.</td>
</tr>
<tr>
<td>COVER METER</td>
<td>One of the few standards for cover meters is BS 1881 Part 204. Alldred (1993) discusses cover meter accuracy when several rebars are close together. Concrete Bridge Development Group Technical Guide 2 (2002) gives good coverage of cover meters, their design an performance.</td>
</tr>
<tr>
<td>METHOD</td>
<td>STANDARDS OR GUIDANCE</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>CHLORIDE CONTENT</td>
<td>CEN has produced a test method for chloride analysis. Products and systems for the protection and repair of concrete structures - Test methods - Determination of chloride content in hardened concrete. BS EN 14629.</td>
</tr>
<tr>
<td></td>
<td>There are three relevant ASTM standards; ASTM C1152/C1152M Standard test method for acid soluble chlorides in concrete and mortar; ASTM C1524 Standard test method for water-extractable chloride form aggregate; ASTM C1218/C1218M Standard test method for water soluble chloride in mortar and concrete. ASTM committee G01.14 is also in the process of developing a laboratory test for chloride thresholds for concretes with different admixtures; WK41360 This test method covers the laboratory determination of the chloride-ion threshold for corrosion of reinforcing steel in concrete. The chloride value at which corrosion initiates for steel in concrete is critical in determining the service life of concrete structures. As of now there is no standard method for determining this value, which is used in various service life modelling programs. ACI 2001 gives extensive discussion on thresholds as well as the Table 4.4 above. BRE Digest 444 (2000) has a comprehensive table and cloud data graph of chloride content versus risk based on field data (Figure 4.11).</td>
</tr>
<tr>
<td>REFERENCE ELECTRODE (HALF CELL) SURVEY</td>
<td>Detailed methodologies for undertaking reference electrode potential surveys and their interpretation can be found in Concrete Society (2004), Chess &amp; Grønvold (1996), Elstener (2003) and ASTM C876.</td>
</tr>
<tr>
<td>LINEAR POLARISATION</td>
<td>Guidance on LPR comes from Concrete (2004), Andrade et al. (2004) and from the manuals provided by manufacturers and suppliers of the equipment.</td>
</tr>
<tr>
<td>METHOD</td>
<td>STANDARDS AND GUIDANCE</td>
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</tr>
<tr>
<td>RADAR/RADIOGRAPHY</td>
<td>ASTM D4788 gives a standard test method for its application to bridge decks, which can be used as guidance for its application on other concrete elements.</td>
</tr>
<tr>
<td>IMPACT ECHO</td>
<td>ASTM C597 standard test method for pulse velocity through concrete and ASTM C1383 test method for measuring the P-wave speed and the thickness of concrete plates using the impact echo method cover the application of impact echo to concrete structures.</td>
</tr>
<tr>
<td>RADIOGRAPHY</td>
<td>General information regarding radiography of concrete structures can be found in BS 1881: Part 205. Concrete Testing. Recommendations for radiography of concrete. National regulations on ionising radiation should also be consulted.</td>
</tr>
</tbody>
</table>
REFERENCES


ASTM C1202 Standard test method for Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration. American Society of Testing and Materials, West Conshohocken PA.

ASTM G57 Field measurement of soil resistivity using the Wenner four-electrode method American Society of Testing and Materials, West Conshohocken PA.

ASTM G 109 Test Method for determining the effects of chemical admixtures on the Corrosion of embedded Steel Reinforcement in Concrete exposed to Chloride Environments American Society of Testing and Materials, West Conshohocken PA.


ASTM C1383 Test method for measuring the P-wave speed and the thickness of concrete plates using the impact echo method American Society of Testing and Materials, West Conshohocken PA.


BS EN 14629 Products and systems for the protection and Determination of Chloride content in hardened concrete. British Standards Institute, London.


Concrete Society Technical Report 54 - Diagnosis of Deterioration in Concrete Structures.

CPA Technical Note 1: Reinforced Concrete, History, Properties & Durability


EN 1504-10, *Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 10: Site application of products and systems and quality control of the works*


