Corrosion is a natural process that occurs when the steel rebar within reinforced concrete structures rusts. In scientific terms, concrete corrosion is defined as the "destruction of metal by chemical, electrochemical, and electrolytic reactions within its environment." It typically forms as the concrete ages

Why Is Concrete Corrosion a Problem?

Corrosion is initiated when materials that are harmful to steel, such as CO2 and chloride from de-icing salt, start to penetrate concrete and reach the steel reinforcement. As an electrochemical reaction, electrons migrate from the anodic zone to the cathodic zone, releasing ferrous ions at the anode and hydroxide ions at the cathode. This will eventually lead to a potential difference between the anodic and cathodic areas at the surface of the steel reinforcement. This results in the creation of rust as a by product. Since rust occupies a larger volume than steel, it exerts internal pressure which causes the surrounding concrete to crack and become damaged. These cracks make their way to the surface of the concrete which causes even more CO2 and chloride to penetrate the concrete and speed up the process of corrosion.

> Corrosion is responsible for up to 90% of damage to reinforced concrete structures.
>
> -Ueli Angst, Professor, Institute for Building Materials

The Cost of Concrete Corrosion

Reinforced concrete structures must be tested regularly to detect and prevent corrosion. As these structures get older, the risk of corrosion in reinforcing steel continues to increase. This is especially important since a large number of structures were built using reinforced concrete between the 1950s and 1970s, especially in bridges.

In North America, the average age of the continents' 607,380 bridges currently in operation is 42 years old, with some of these structures as old as 80 years. Not only that, but one in nine of these bridges is considered structurally deficient and nearing the end of their initial service life (ASCE). Consequently, these structures require more frequent testing and repairs to eliminate damage and slow down the corrosion process.

Since concrete is the most widely used manufactured material globally, the industrialized world faces billions of dollars in concrete testing and repair costs. This is essential in order to keep structures sound and functional. In Switzerland alone, the annual cost of repairs can amount to between $6.6-$26.3 billion CAD. When taking this information into consideration, it is extremely important to accurately assess the condition of reinforced concrete structures in order to decide if repairs are required immediately.

Assessing Corrosion in Reinforced Concrete Structures

Extraction of concrete samples is a key process in the condition assessment of reinforced concrete structures. The typical sample size taken from concrete structures for laboratory testing are about 5 to 20 centimeters. Recent studies have shown that although these sample sizes are ideal for handling in the laboratory, they often show higher concentrations of corrosive chloride than larger specimens and may provide inaccurate results.

According to Angst, only larger specimens, of about one meter in length, present an accurate assessment of the condition of the reinforced concrete. However, these larger samples are much less practical to work with, which makes proper testing more difficult and more expensive. Not to mention the level of destruction to the body of concrete. Scientists believe switching to expensive high-alloy steel is the only way to prevent corrosion damage entirely. Although, high-alloy steel costs nearly ten times more than traditional reinforcing steel and would increase initial production costs of a project. It would, however, reduce the costs associated with regular inspection and repairs in the long run, making it a cheaper and more durable alternative.

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New Corrosion Detection Technology

Photo credit: University of Nebraska-Lincoln College of Engineering

Although high-alloy steel is a great way to prevent corrosion damage, common reinforcing steel is more realistic for budgets and is already present in the majority of today's reinforced concrete structures. For this reason, repair of rebar has been the focus. As buildings age and concrete corrodes, engineers keep searching for cheaper, more effective ways to test for corrosion. New non-destructive testing methods and technologies can help deliver more accurate results and cut down on costs associated with other corrosion detection methods.

In 2017 alone, two additional systemswere introduced to the market, one of which is mounted on a small skid-steer robot, the other of which is mounted in a cart that can be towed along a roadway. Both of these corrosion detection systems make use of machine learning technology and don't require any sort of destructive intervention to gather results. The robot-mounted system utilizes ground penetrating radar and electrical resistivity sensors to locate any corrosion of steel or deteriorating concrete in bridges and structures. It is also fully autonomous and has proved to be faster and more accurate than human inspectors.

Jinying Zhu, Assistant Professor of Civil Engineering at the University of Nebraska-Lincoln, has designed a system to detect defects in concrete bridge decks. Her approach is an early-warning system for bridges based on acoustics. It has proven to be a more accurate alternative to other methods of identifying delamination, a gradual separation of concrete layers that can affect the structural integrity of a bridge or structure and can be caused by rebar corrosion. Her system also delivers much faster results than conventional testing methods allowing people to find delamination in a timelier manner and make the necessary repairs before the damage becomes too significant.

iCOR®: Non-destructive Concrete Corrosion Monitoring

Another cost effective and proven method of detecting corrosion is the iCOR®. This device measures the electrical response of the reinforcement inside the concrete without a physical connection to the rebar. As a non-destructive testing tool, the iCOR® is an award-winning device that has been recognized for its positive impact in corrosion monitoring and mitigation. Using our patented Connectionless Electrical Pulse Response Analysis (CEPRA) technology, the device is unique in its ability to perform three-in-one concrete testing measurements of: rebar corrosion rate, half-cell potential, and in-situ electrical resistivity. These measurements are critical to the success of rehabilitation projects and to the repair of concrete structures.

For this reason, the iCOR® is the most convenient corrosion rate measurement device in the field and offers an innovative research tool for laboratory studies as well. It gives engineers a comprehensive understanding of concrete quality and the level of corrosion; ultimately, it allows them to make faster, more informed decisions when it comes to rehabilitation and repair.

Editor's Note: This post was originally published in June 2018 and has been updated for accuracy and comprehensiveness.