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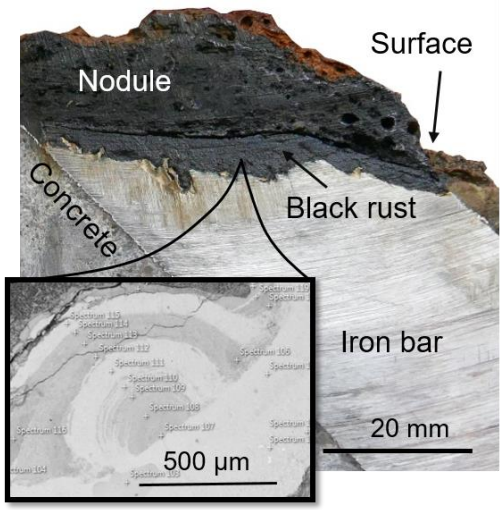
Black corrosion consumes reinforcing bars in concrete

The process of black corrosion has been found to break down the reinforcing steel, and damage the neighboring concrete, in water saturated concrete structures. Over time, this phenomenon may pose a danger to the stability of the affected buildings. Therefore, it is important to find out more about this process, what black corrosion is and how it affects the concrete.

Black rust is the name of iron-based corrosion products formed during the black corrosion process of steel. The dark color and soft, mud-like texture are characteristics of these products that form during oxygen poor conditions. Samples of concrete drill cores have been carrying some of the answers to these quests. When looking at the black rust with higher magnification, it was possible to see a cyclic pattern – layers that tend to be made of alternating *ferrous* (Fe^{2+}) and *ferric* (Fe^{3+}) iron oxides or hydroxides. This pattern is likely related to a complex process of resolution and reprecipitation of the corrosion products. Some of the products found around the iron bars were more chloride-rich and have been identified as a chloride variety of green rust, GR(Cl^-). Green and black rust are different products that seem to evolve in similar environmental conditions and could even be related to each other. Different grades of oxidation and dehydration of green rust have resulted in black rust formation. Further oxidation of black rust will quickly form the typical red rust that we often know as rust on our cars and bikes.

The corrosion process has also been found to impact the cement paste chemistry. A lowered pH-level resulted in leaching of the major cement paste constituents – calcium (Ca), aluminum (Al) and silica (Si), causing a weakened and more porous cement paste. This makes a perfect hideout for the black rust. Ettringite, portlandite and gypsum were discovered in cavities in the concrete. These are minerals which reveal information about the environment where this corrosive process takes place.

One major problem with black rust and black corrosion is the difficulty of detecting it. Often the problem is hidden behind the concrete wall without any outer signs of degradation, such as cracks. This can be explained by the low availability of oxygen in the corrosive environment. Iron is dissolved from the rebar and will then stay in solution long enough to be transported away through the pore system. The transport is mostly caused by *diffusion* (a spontaneous spreading process occurring in gases or fluids). The dissolved iron can get trapped in voids and cracks or precipitate at the surface of the concrete wall where it forms nodules. These rust nodules can potentially be used as an indicator to find black corrosion.



The black rust has replaced the upper most part of the iron bar and in the transition pit corrosion have started to breaking down the iron further. A nodule covers the top like a lid and prevents oxygen from reaching the corrosion area. With higher magnification the cyclic pattern can be seen.

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