Self-healing concrete repairs cracks, maintains strength

Researchers at the University of Michigan (U-M) (Ann Arbor) have developed a fiber-reinforced cementitious composite that can automatically heal itself when it cracks and still be able to maintain its load strength. The researchers note that this new composite could make infrastructure safer and more durable, and by mitigating the corrosion process, reduce the cost and environmental impacts of building new structures. The new concrete material requires only water and air for repair, and researchers say a handful of rainy days would be enough to mend a damaged bridge made of this new substance.

In addition to negatively affecting the mechanical performance and durability of concrete structures, cracking also reduces a structure's load capacity and stiffness. Concrete structures are usually reinforced with steel bars to keep cracks as small as possible, the researchers say, but these cracks are too large for self-healing, and water and deicing salts are able to migrate through the cracked concrete and corrode the reinforcing bars. This creates the concrete to spall and further weaken the structure. The self-healing concrete composite developed by the U-M researchers is able to bend, and any cracks caused by stress are extremely narrow.

According to the material's inventors, Victor Li, the E. Benjamin Wylie Collegiate Professor of Civil Engineering and a professor of materials science and engineering at U-M, and Han-Hua Yang, the self-healing mechanism in concrete is caused by the formation of calcium carbonate (CaCO3), a strong compound containing naturally in seashells, resulting from the reaction between unhydrated cement and carbon dioxide (CO2) dissolved in water. Concrete is unique in that it inherently contains micro-reservoirs of widely dispersed unhydrated cement particles that are available for self-healing. In most concrete, and particularly in those with a low water/cement ratio, the amount of unhydrated cement particles is expected to be as much as 25% or higher. When concrete cracks, the unhydrated cement particles are exposed to water and CO2 present in the environment and combine with them to form a thin white healing layer of CaCO3.

The self-healing composite works because the new fiber-reinforced cementitious composite, an improvement on an earlier generation of the bendable, engineered cement composite (BCC) that U-M scientists have been developing for the last 15 years, is engineered to bend and crack in narrow hairline fissures rather than break and split in wide gaps like traditional concrete.

"We've created a material with such tiny crack widths that it takes care of the healing by itself. Even if you overload it, the cracks stay small," Li explains. In the research lab, self-healed composite specimens recovered most of not all of their original strength after researchers subjected them to a tensile strain of 3%, which means stretching the specimen 3% beyond its initial size. It's the equivalent of stretching a 100-ft (30-m) piece of composite an extra 3 ft (0.9 m) — enough strain to severely deform metal or catastrophically fracture traditional concrete. The average crack width in the researchers' self-healing composite is below 60 μm, about half the width of a human hair. For most practical service conditions the material strains are substantially less than 1% and microcracks, which can be as small as 10 to 20 μm, will heal effectively, Li says.

The white lines on this specimen of bendable concrete show where the material has healed itself by forming CaCO3. This specimen has undergone deliberately introduced damage and succeeding self healing numerous times, illustrating the resiliency necessary for field structures that may undergo multiple overloads during their lifetime. Photo by Nicole Casal Moore, University of Michigan News Service.
Corrosion-resistant coatings incorporate metal oxide nanoparticles

As an example, aluminum (Al) is a common metal used in various applications, such as automotive and aerospace industries. Al films are often coated with metal oxide nanoparticles to improve their corrosion resistance. The process of integrating these nanoparticles into the coating matrix is crucial for achieving effective corrosion protection.

Traditionally, the formation of a barrier layer on the metal surface is achieved through the application of a protective coating. However, this approach is limited by the formation of a corrosion product that can crack and peel away from the substrate.

The introduction of metal oxide nanoparticles into the coating matrix can significantly enhance its corrosion resistance. These nanoparticles act as a barrier, preventing the penetration of corrosive agents to the underlying metal. As a result, the coating life is extended, and the need for frequent maintenance is reduced.

Key Features:
- Improved corrosion resistance
- Enhanced adhesion to the substrate
- Reduced coating thickness
- Increased durability

Incorporating metal oxide nanoparticles into the coating matrix can be achieved through various methods, such as sol-gel processing or spraying. These techniques allow for the uniform distribution of nanoparticles throughout the coating, ensuring optimal performance.

Conclusion:
Corrosion-resistant coatings incorporating metal oxide nanoparticles represent a significant advancement in the field of materials science. Their ability to enhance corrosion resistance makes them an ideal choice for applications where durability and longevity are critical factors.