Use of Cold Gas Dynamic Spraying for Repair of Steel Structures

tech transfer summary

BRIDGE ENGINEERING CENTER

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RESEARCH PROJECT TITLE
Use of Cold Gas Dynamic Spraying for Repair of Steel Structures

SPONSORS
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PRINCIPAL INVESTIGATOR
Behrouz Shafei, Associate Professor
Bridge Engineering Center
Iowa State University
shafei@iastate.edu / 515-294-4058
(orcid.org/0000-0001-5677-6324)

MORE INFORMATION
intrans.iastate.edu

Bridge Engineering Center
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103
www.bec.iastate.edu

IOWA STATE UNIVERSITY
Institute for Transportation

Cold gas dynamic spraying offers a durable treatment that can be applied simply and quickly to repair and retrofit corroded steel structures.

Objectives

This research project aimed to investigate the feasibility of using cold gas dynamic spraying (CS) for the repair and retrofit of corroded steel members.

Problem Statement

A growing investment is made every year in the repair and replacement of deteriorating structures. For steel structures in particular, corrosion is the main cause of deterioration, which adversely affects the long-term integrity and performance of this category of structures.

Background

In CS, an inert gas such as helium or nitrogen is accelerated up to two or three times the speed of sound (1,000–1,200 m/s) and entrained with micron-sized (10–70 μm in diameter) metallic or alloy particles that are deposited onto the surface of a substrate. During the cold spraying process, the particles remain well below their melting temperature.

Adhesion of the particles to the substrate can be fully achieved when the particles exceed a critical impact velocity during cold spraying. The critical impact velocity substantially depends on the particle and substrate material properties and environmental conditions such as the temperature and pressure of the gas.

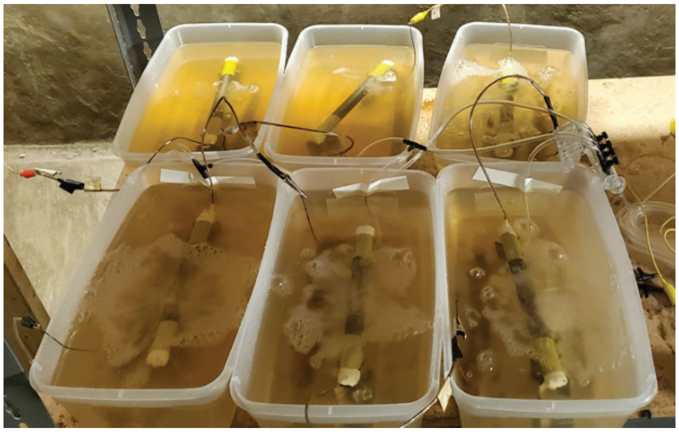
Research Description

The experimental program included accelerated corrosion testing, application of a protective coating using CS, and tensile and hardness tests.

Accelerated Corrosion Testing

Accelerated corrosion testing was conducted in accordance with ASTM G31 on three types of metal specimens shaped into 8-inch-long coupons: aluminum, ASTM A1010 corrosion-resistant steel, and ASTM A36 steel. The coupons were submerged in saltwater solution, and a current was run through the solution to simulate pitting corrosion for 7 and 14 days.

After the initial corrosion tests, the corroded samples of ASTM A36 steel were brushed to remove rust, and the mass lost from corrosion was replaced using one of two cold spray coatings: aluminum or Inconel. Accelerated corrosion testing was conducted again with the cold-sprayed steel coupons.



Accelerated corrosion testing on ASTM A36 steel coupons

Steel coupons with the mass lost due to corrosion repaired using cold spray coating

Tensile and Hardness Testing

Tensile tests were performed to study the average yield strength, elongation, and modulus of elasticity of ASTM A36 steel specimens with six types of treatment: corroded (5% loss), corroded (20% loss), uncorroded and coated with aluminum, uncorroded and coated with Inconel, corroded and coated with aluminum, and corroded and coated with Inconel.

A Rockwell A hardness test was used to determine the hardness of uncorroded ASTM A36 steel specimens coated with aluminum or Inconel.

Key Findings

Accelerated Corrosion Testing

1. For the 7-day testing period, the average loss was 4.5% for A36 steel, 5% for A1010 steel, and 10% for aluminum. For the cold-sprayed coupons, the average losses were 4.4% and 1.2% for the coupons coated with Inconel and aluminum, respectively.
2. For the 14-day testing period, the average loss was 20% for A36 steel, while the average losses were significantly lower for the cold-sprayed coupons coated with Inconel and aluminum, 4.0% and 3.1%, respectively.
3. A comparison between the Inconel- and aluminum-coated specimens revealed that the Inconel-coated bars had higher corrosion rates in both tests and appeared significantly more corroded than the aluminum-coated bars. The aluminum-coated bars had more consistent corrosion, lower corrosion rates, and less severe corrosion, making aluminum the more effective protective coating.

Tensile and Hardness Testing

1. It was found that the differences in tensile behavior among the cold-sprayed specimens were not directly related to the coating. This might be because the coated layer was thin for these steel samples.
2. The bonding between the substrate steel and the coating material was found to be in need of attention after the steel began to yield.
3. From the hardness testing, the cold-sprayed steel coupon coated with Inconel had a Rockwell A hardness value of 77.5. However, the hardness of the cold-sprayed steel coupon coated with aluminum was found to have a Rockwell A hardness value of 11.2 because the aluminum coating significantly softened the material.

Implementation Readiness and Benefits

For state departments of transportation (DOTs), CS has the potential to improve the repair and retrofit of steel structures, especially in bridges, by providing a durable treatment that can be applied simply and quickly using a portable device. Coated steel members would not only regain their lost structural capacity but also become more resistant to corrosion, greatly extending their lifespan and minimizing repetitive maintenance.

The outcome of this research not only demonstrates the promise of this emerging technique but can also be used to help tailor CS for transportation infrastructure applications. This contribution will maximize the impact of this innovative technique, which holds great promise for future use and implementation.