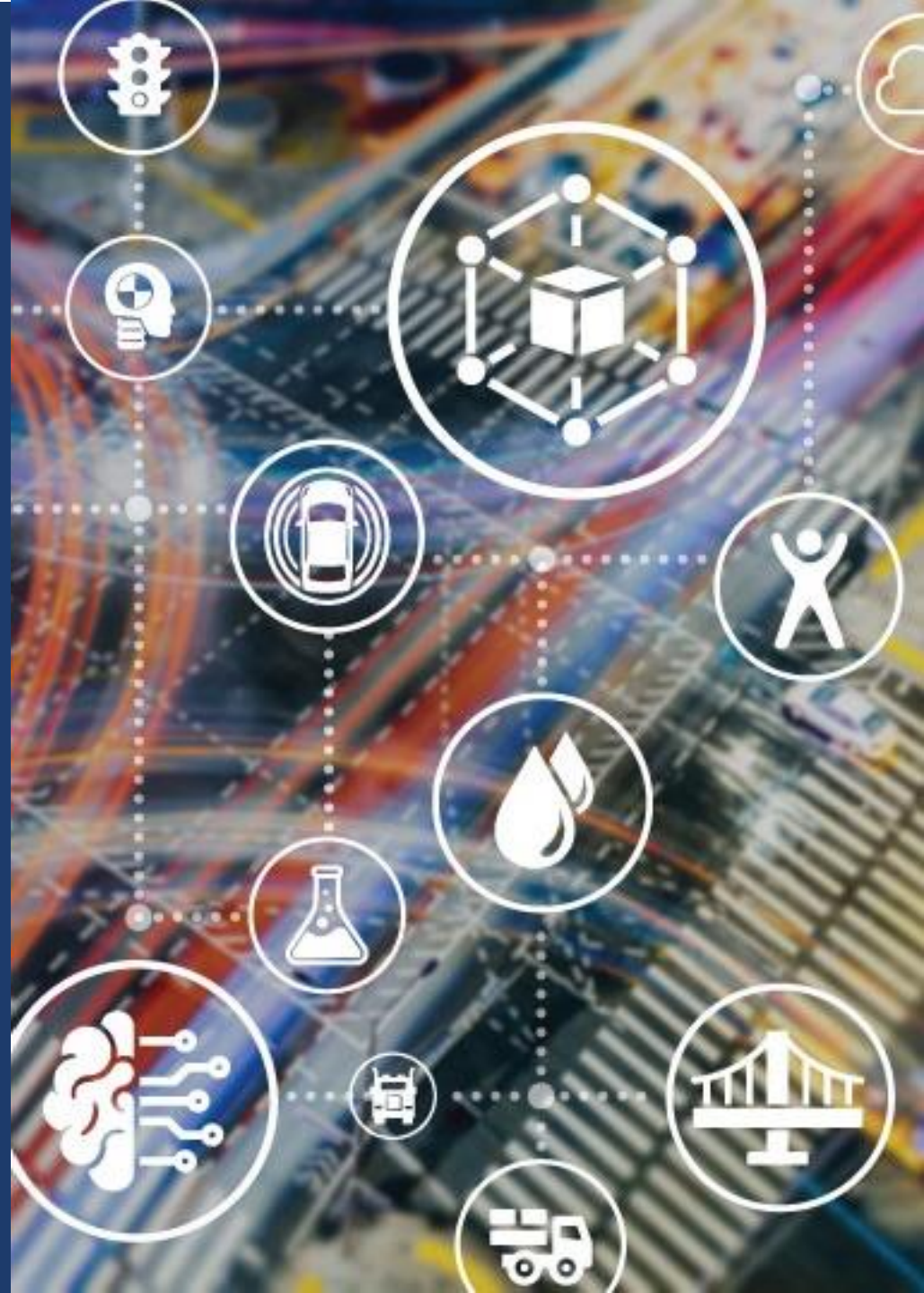
U.S. Department of Transportation
Federal Highway Administration

Turner-Fairbank Highway Research Center

Federal Highway Administration (FHWA) Coatings and Corrosion Laboratory (CCL): Ongoing Research on Coatings

Office of Infrastructure Research and Development
FHWA CCL
October 2023

Frank Jalinoos
Coatings and corrosion lab manager
Long-Term Infrastructure Performance Team



Outline

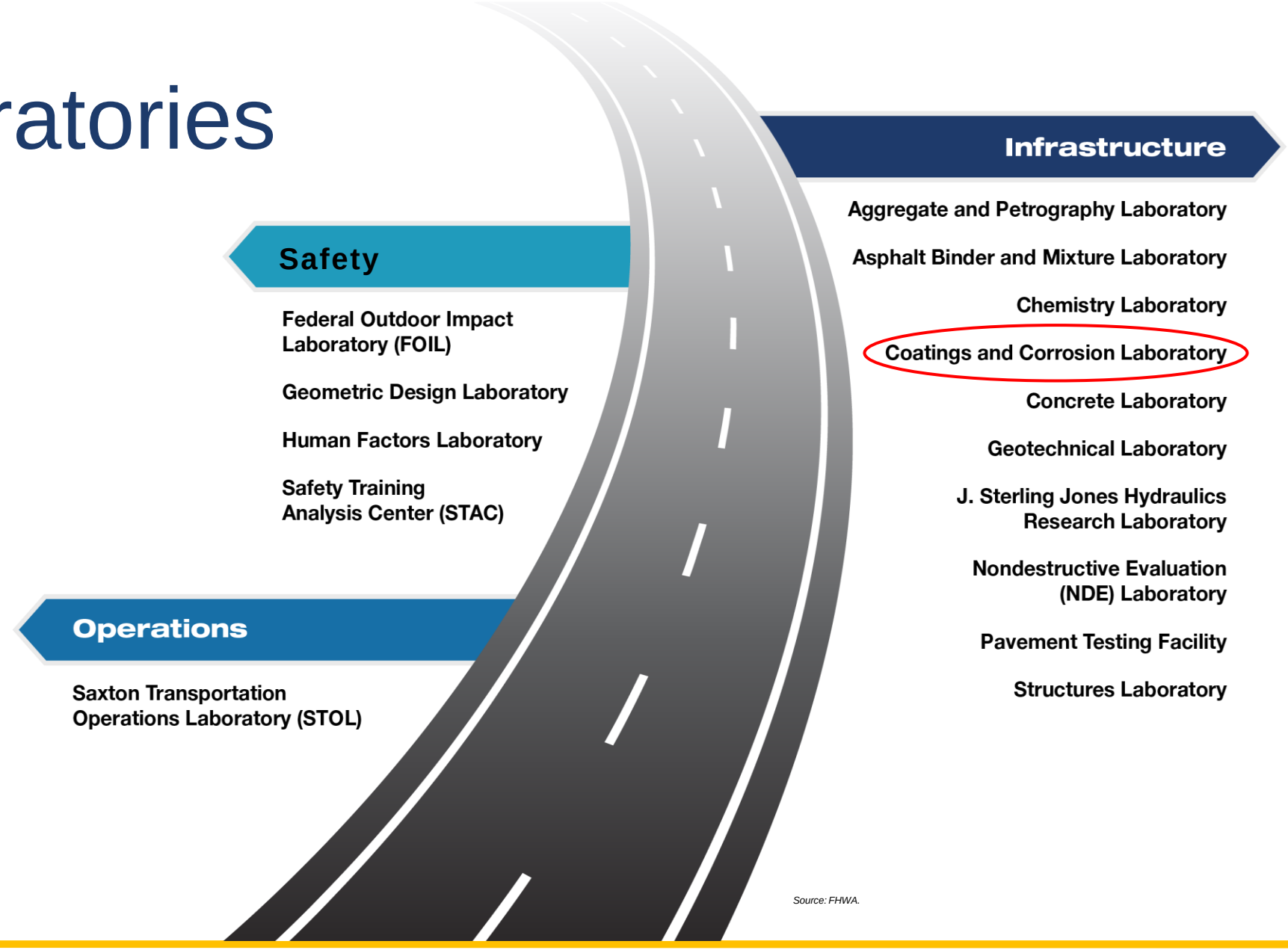
- CCL expertise, mission, and research disciplines.
- CCL current coatings research projects:
  - Corrosion performance of metalized coatings over contaminated steel substrate.
  - Performance of coating systems used for preventive maintenance.

Turner-Fairbank Highway Research Center Expertise

- Structural design and performance.
- Pavement design and evaluation.
- Safety design and operations.
- Human factors analytics.
- Connected vehicle technologies.
- Intelligent transportation systems.

Source: FHWA.

Laboratories



Infrastructure

- Aggregate and Petrography Laboratory
- Asphalt Binder and Mixture Laboratory
- Chemistry Laboratory
- Coatings and Corrosion Laboratory
- Concrete Laboratory
- Geotechnical Laboratory
- J. Sterling Jones Hydraulics Research Laboratory
- Nondestructive Evaluation (NDE) Laboratory
- Pavement Testing Facility
- Structures Laboratory

Safety

- Federal Outdoor Impact Laboratory (FOIL)
- Geometric Design Laboratory
- Human Factors Laboratory
- Safety Training Analysis Center (STAC)

Operations

- Saxton Transportation Operations Laboratory (STOL)

Source: FHWA.

CCL Goals

1. Conduct research to discover innovative solutions for the most critical materials-related problems that affect durability and serviceability of transportation infrastructure.

2. Focus on research that can yield field-applicable results.

3. Make the Nation's infrastructure safer and last longer by providing useful research products to stakeholders (e.g., State and local highway agencies, industries, and academia).

Corrosion Modeling and Simulation

Data sources:

- Construction documents.
- Field assessment.
- Laboratory testing.

Modeling corrosion:

- Chloride ingress.
- Corrosion initiation and propagation.
- Corrosion damage to steel and concrete.

Source: FHWA.

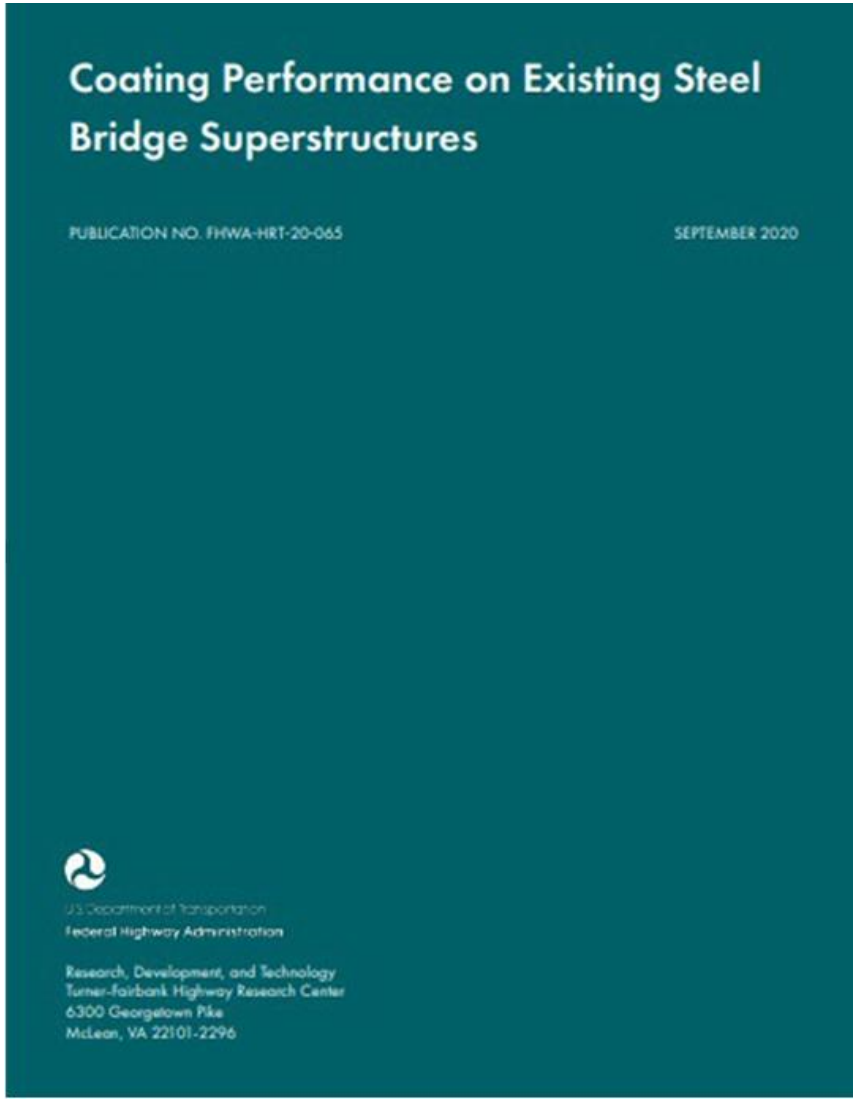
CCL Current and Recently Completed Coatings Research Projects

U.S. Department of Transportation
Federal Highway Administration
Turner-Fairbank Highway Research Center

Recently Completed Coatings Research Projects

- *Report on Industry-Recognized Corrosion Prevention Worker Certifications Effectiveness Evaluation, as Requested by the Senate Report 114-243 and House Report 114-606* (a congressionally mandated study) (Becker and Kogler 2019).
- *Coating Performance on Existing Steel Bridge Superstructures* (which focused on coating performance over chloride-contaminated substrates) (Liu and Runion 2020).
- *Innovative Coating Removal Techniques For Coated Bridge Steel* (which evaluated the performance of laser versus grit-blasting coating removal) (Fitz-Gerald et al. 2019).

Coating Performance on Existing Steel Bridge Superstructures



Source: FHWA (Liu and Runion 2020).

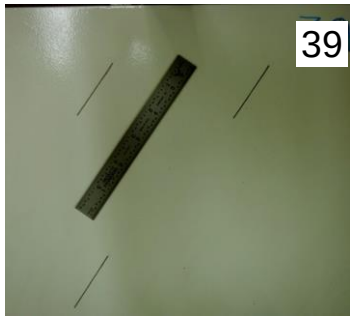
.

Coating Performance on Existing Steel Bridge Superstructures (Continued)

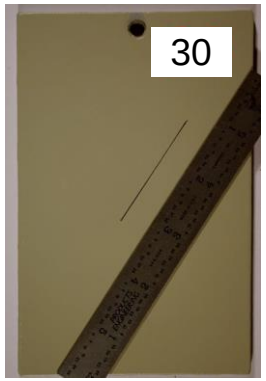
- Evaluated four coatings over intentionally contaminated surfaces:
  - A three-coat system with an inorganic zinc-rich primer.
  - A three-coat system with an organic zinc-rich primer.
  - A two-coat system with zinc-rich primer with carbon nanotubes and urethane topcoat.
  - A one-coat system of high-ratio calcium sulfonate alkyd.
- Developed substrates with three levels of chloride contamination:
  - Control: less than 1-µg/cm^2.
  - –20-µg/cm^2.
  - –60-µg/cm^2.

Outdoor Exposure Testing

All photos source: FHWA.



Scribes in coating.



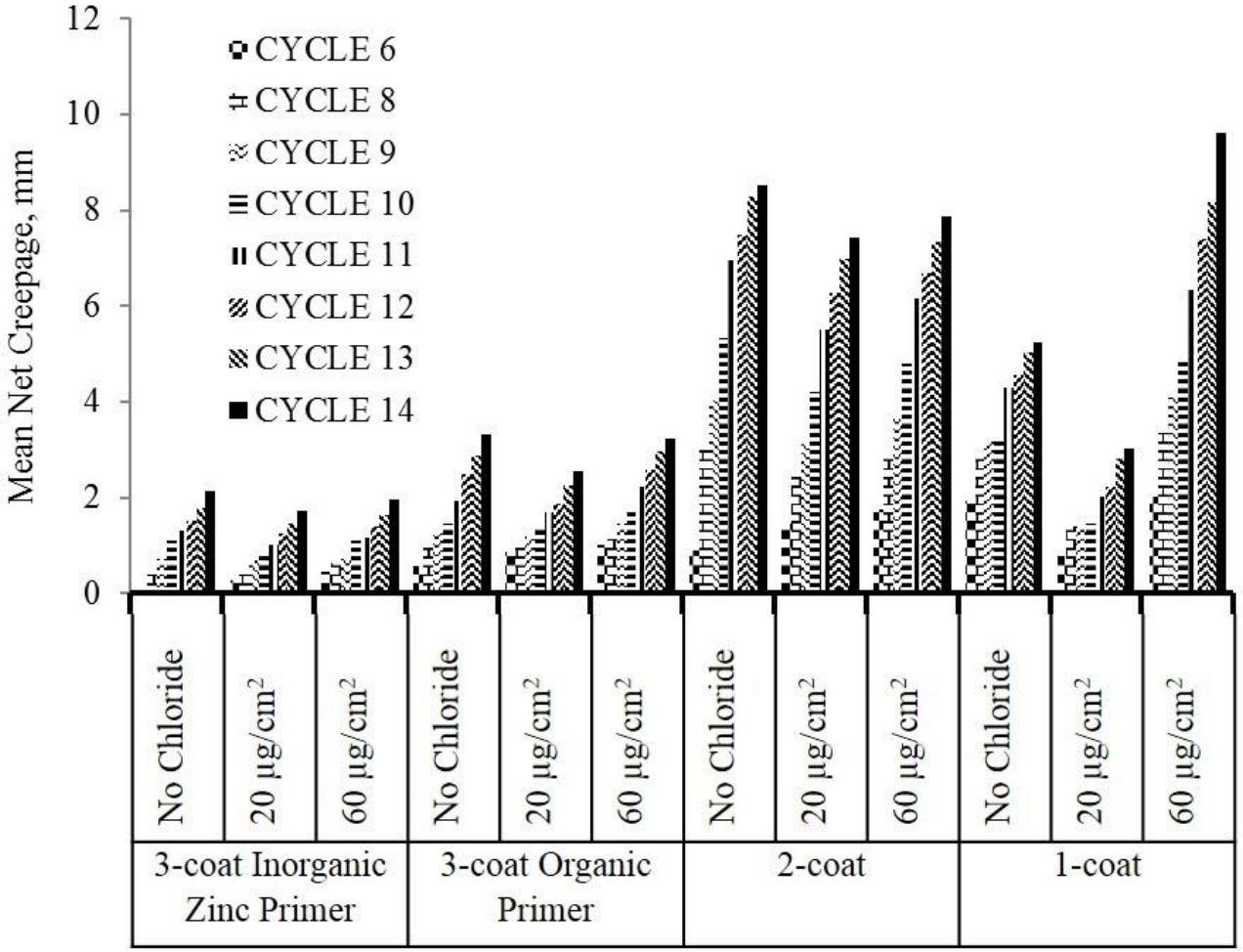
Accelerated Lab Testing (ALT)

All photos source: FHWA.

Salt fog chambers

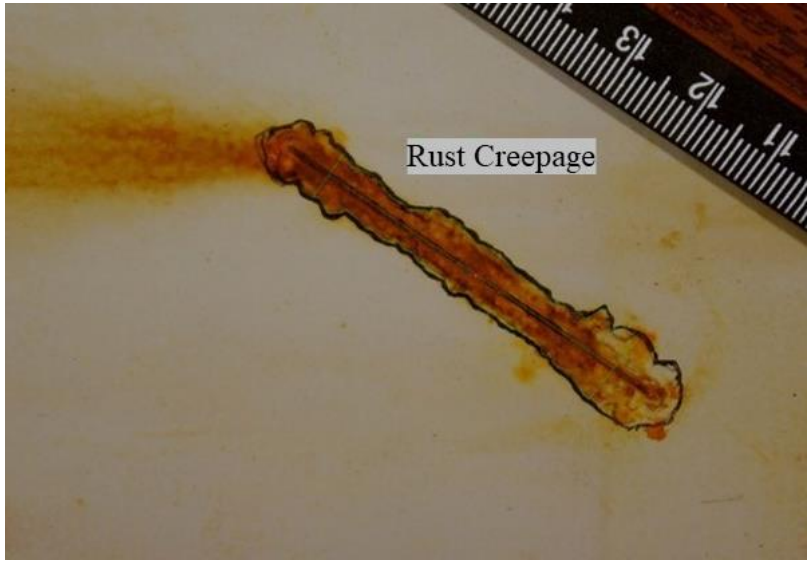
Ultraviolet chamber.

ALT



All photos source: FHWA.

Rust creepage development on ALT panels.



Rust creepage measurement.

Coating Performance—Conclusions

- The three-coat systems showed better tolerance of chloride than the two- and one-coat systems. The three-coat system with inorganic zinc primer had the best tolerance of chloride.
- The inorganic zinc primer performed slightly better than the organic zinc primer with chloride contamination levels up to 60-μg/cm^2.
- Spraying saltwater did not affect the performance of the three-coat systems. The two-coat panels subjected to saltwater spray developed significant rust creepage, whereas the panels exposed to water spray did not exhibit noticeable creepage.
- Outdoor weathering simulates the natural exposure conditions experienced by steel bridges in service. However, the testing time should be significantly longer than ALT.

Current Coatings Research Projects

- Corrosion performance of metalized coatings over contaminated steel substrate (metalizing/galvanizing performance over chloride-contaminated substrate).

- Performance of coating systems used for preventive maintenance.

Corrosion Performance of Metalized Coatings Over Contaminated Steel Substrate

Corrosion Performance of Metalized Coatings Over Contaminated Steel Substrate (Continued)

- Evaluate the performance of thermal spray coatings on contaminated steel substrates.
- Evaluate three coating types (i.e., zinc, aluminum, and zinc/aluminum (85-percent zinc and 15-percent aluminum)) over four levels of chloride contamination: 0-, 20-, 60-, and 100-µg/cm^2.
- Coat the specimens with a top sealer.
- Stripe coat the edges with a seal coating.

Metallization

All photos source: FHWA.

Thermal spray operation.

Panel coated with top sealer.

Metalized Coatings—Testing (1/3)

All photos source: FHWA.

Outdoor exposure.

Panels in salt-fog chamber.

Metalized Coatings—Testing (2/3)

Aluminum coated.

Aluminum coated.

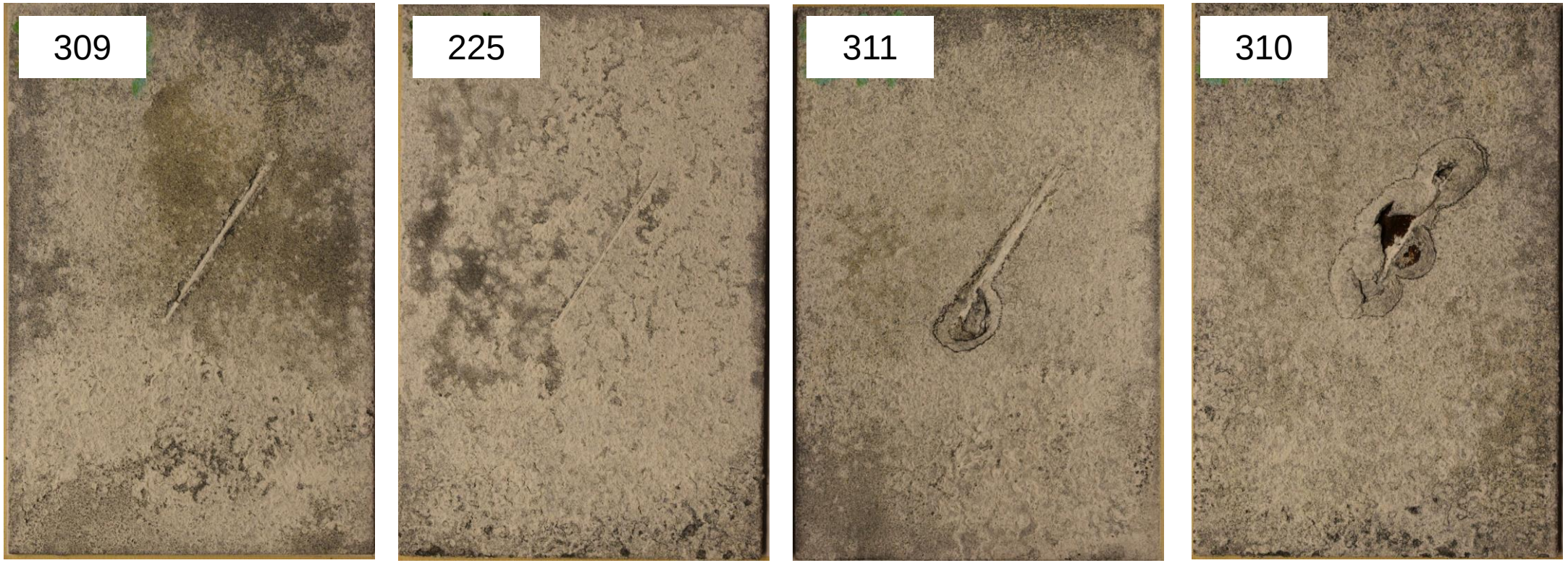
Zinc coated.

Aluminum-zinc coated.

All photos source: FHWA.

Coated panels after 10 ALT cycles.

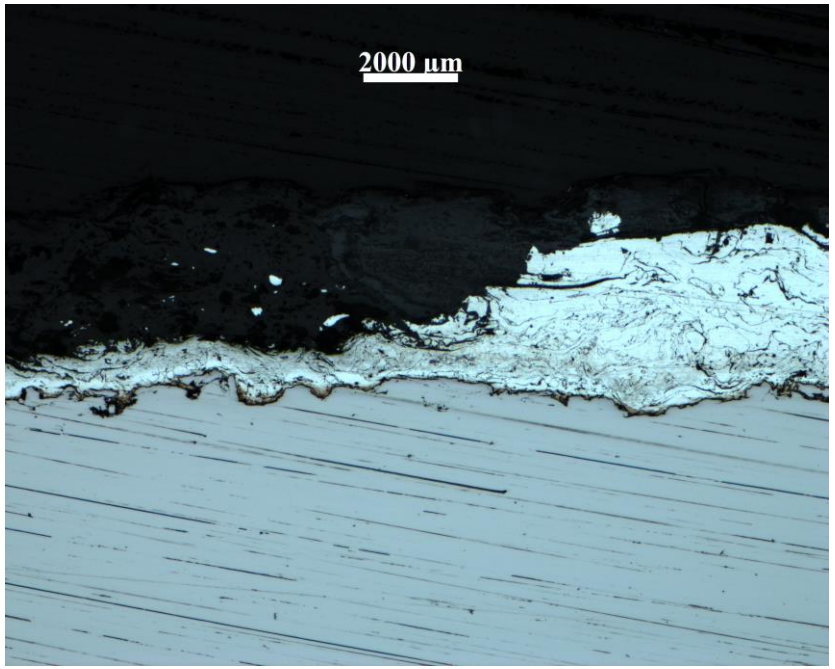
Metalized Coatings—Testing (3/3)



All photos source: FHWA.

Aluminum-zinc-coated panels showing coating failure after 10 ALT cycles.

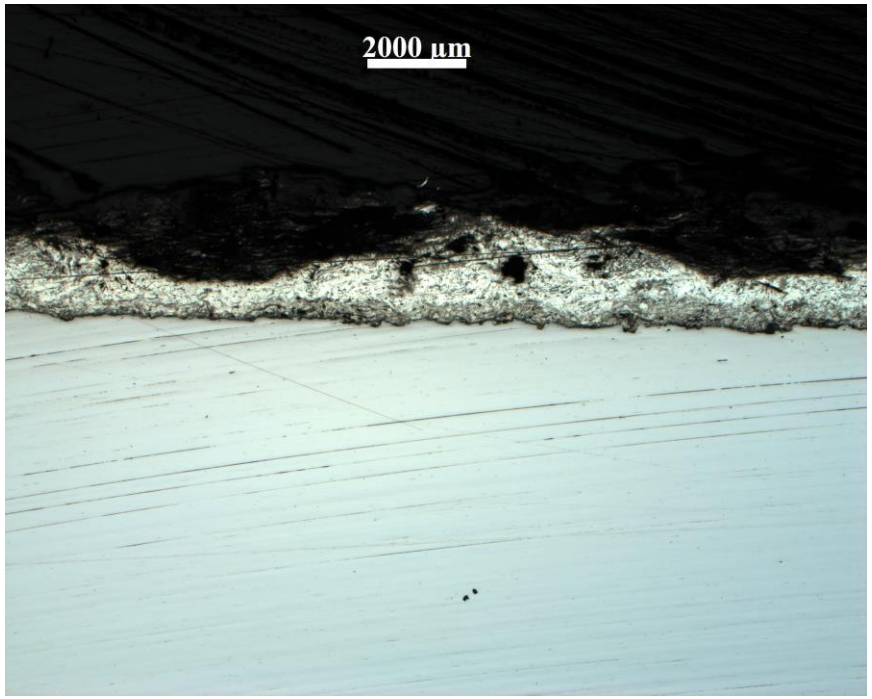
Coating Film Damaged by Corrosion (1/3)



Source: FHWA.

Zinc-coated panels after accelerated lab testing showing coating layer loss (panel number 029).

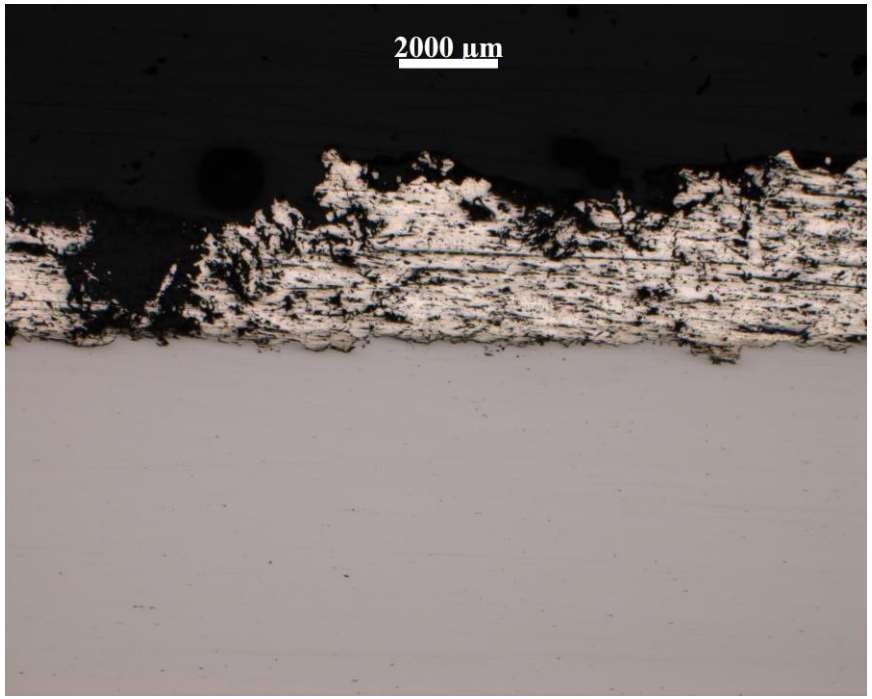
Coating Film Damaged by Corrosion (2/3)



Source: FHWA.

Aluminum-zinc-alloy-coated panels after accelerated lab testing showing coating layer loss (panel number 225).

Coating Film Damaged by Corrosion (3/3)



Source: FHWA.

Aluminum-coated panels after accelerated lab testing showing coating layer loss (panel number 001).

Performance of Preventive Maintenance Coatings

Scope of Study:

- Explore new and advanced coating materials for preventive maintenance and condition-based preservations.
- Evaluate novel surface cleaning methods that are field deployable (e.g., laser ablation).
- Explore field applications for maintenance coating.
- Evaluate the long-term performance of coating systems.

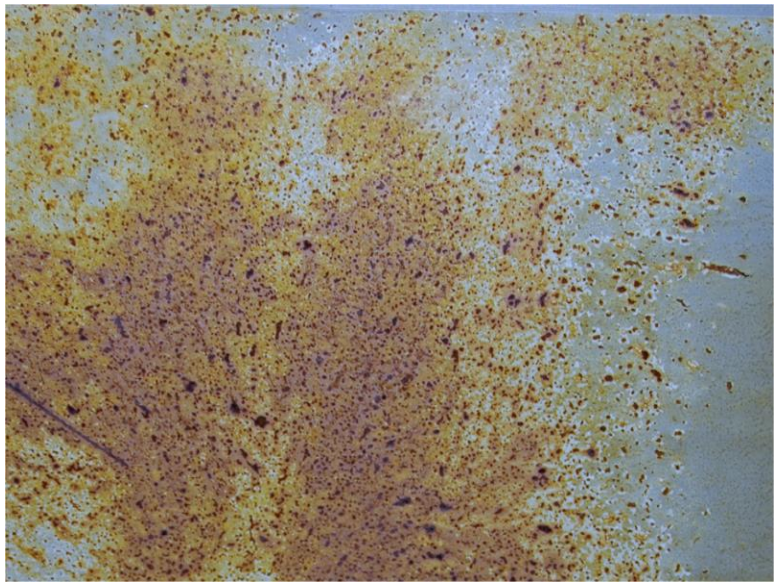
Advanced Coatings for Preventive Maintenance

1. Single-component organic zinc coating: one-coat system containing 96-percent zinc in dry film.
2. Graphene-enhanced primer plus urethane topcoat: increased barrier performance in the primer.
3. Epoxy zinc-rich primer plus urethane topcoat: two-coat system with improved corrosion resistance.
4. Duplex coating system: metallizing plus durable organic coating.

Laser Ablation for Surface Preparation

- Aims nanosecond-length pulses of laser light towards a surface (Adapt Laser n.d.).
- Turns contaminants or coating particles into a gas or peels them from the surface (Adapt Laser n.d.).
- Has benefits for surface preparation (Fitz-Gerald et al. 2019):
  - Is easy to operate (easily automated, quiet, and reliable).
  - Does not require surface cleanup.
  - Does not require containment.
  - Is safe and environmentally friendly.

Laser Ablation for Surface Preparation (Continued)



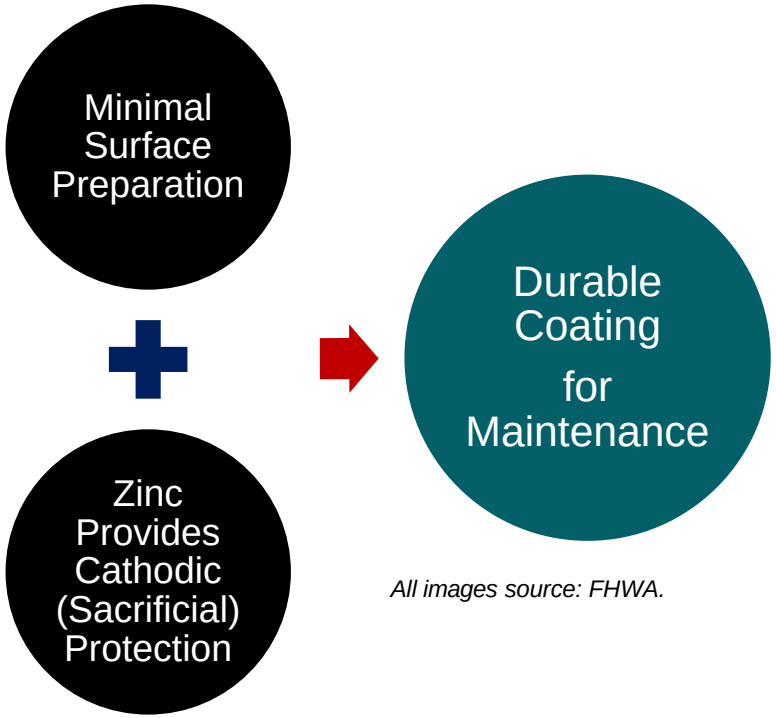
All photos source: FHWA.

Before.

After.

Laser ablation for coating removal and surface preparation.

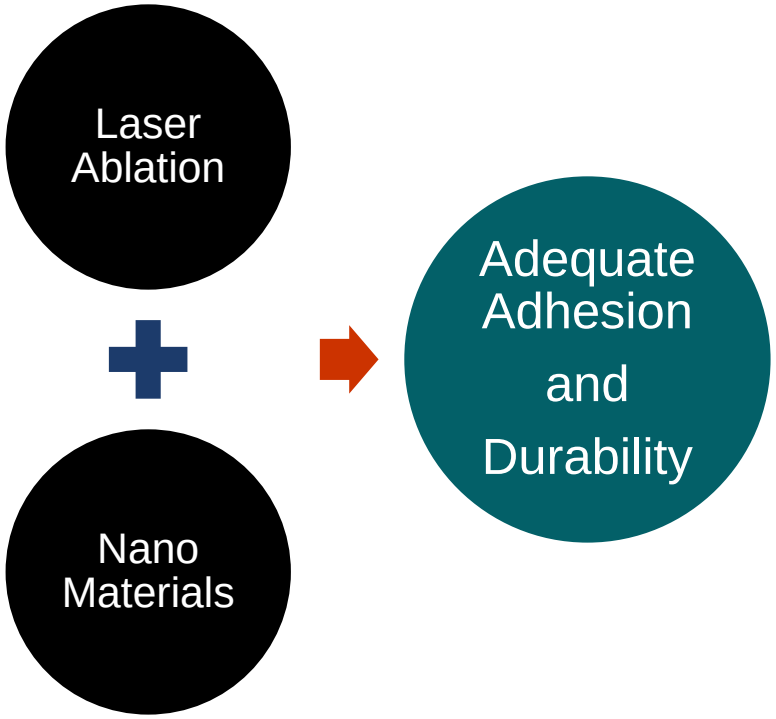
Coating Systems: Single Coat



All images source: FHWA.

Single-component organic zinc coating.

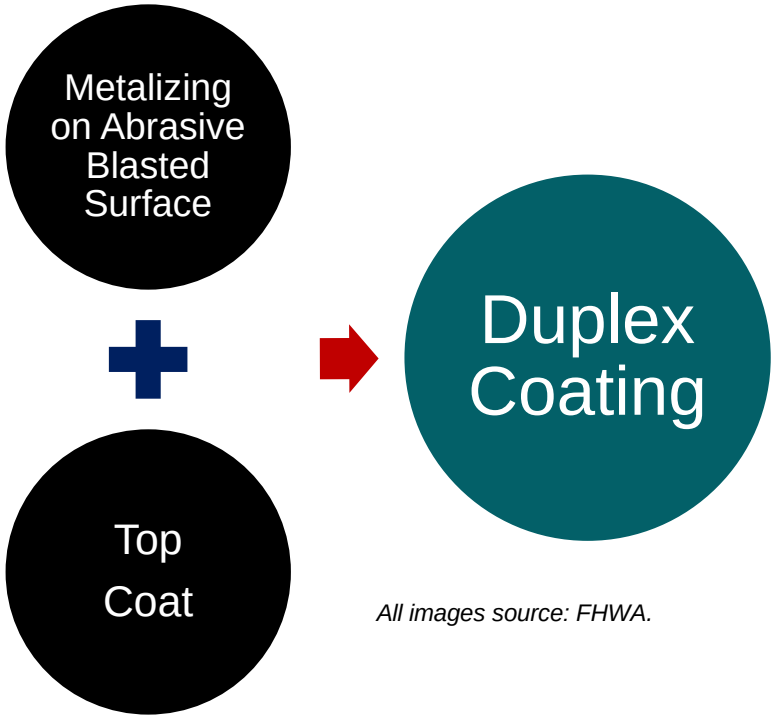
Coating Systems: Two Coat



All images source: FHWA.

- Zinc-rich primer.
- Graphene-enhanced primer.
- Laser-ablated steel surface.

Coating Systems: Duplex Coatings



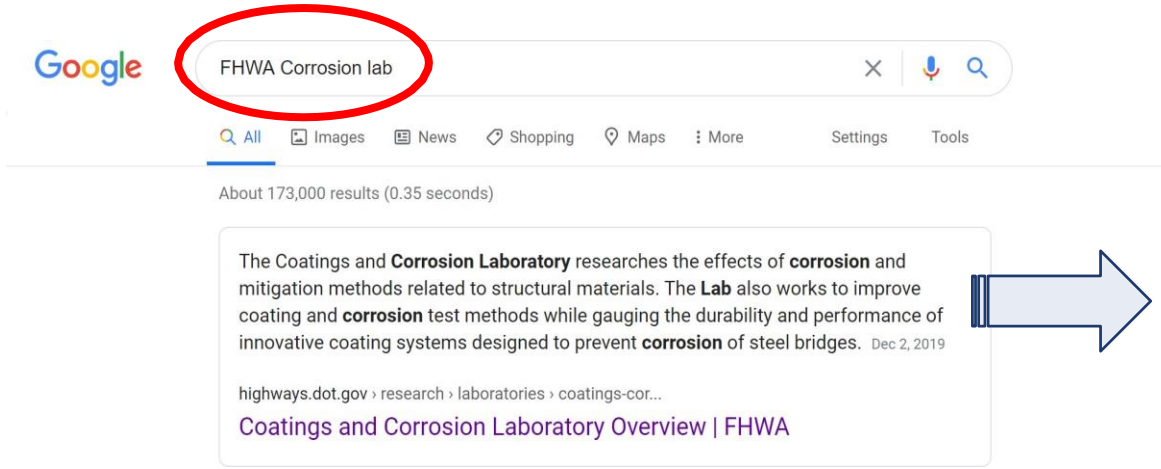
All images source: FHWA.

- The thermal spray (metalizing) zinc coating is on the abrasive blasted steel substrate.
- The topcoat provides extra barrier protection.

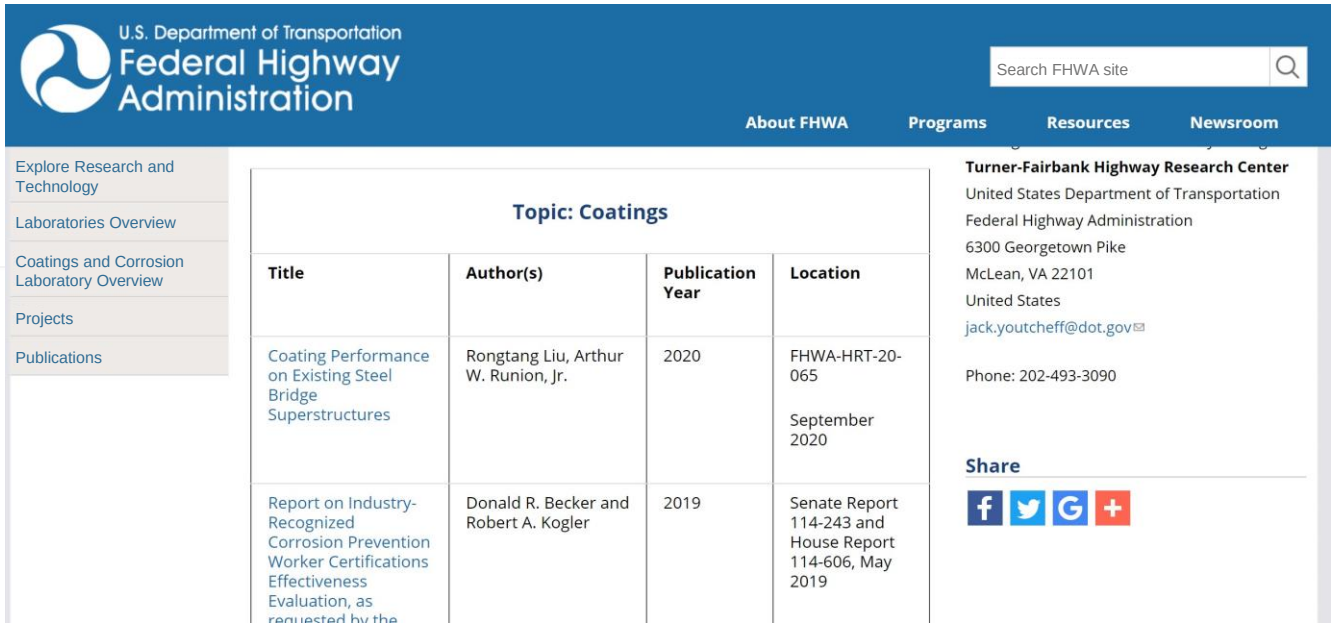
CCL Web Page

https://highways.dot.gov/research/laboratories/coatings-corrosion-laboratory/publications (FHWA n.d.)

Google® search: “FHWA Corrosion Lab”



© 2020 Google.



Source: FHWA (FHWA n.d.).

.

References

Adapt Laser. n.d. “How Laser Cleaning Works” (web page). https://adapt-laser.com/how-laser-cleaning-works, last accessed March 28th, 2023.

Becker, D. R., and R. A. Kogler. 2019. *Report on Industry-Recognized Corrosion Prevention Worker Certifications Effectiveness Evaluation, as Requested by the Senate Report 114-243 and House Report 114-606*. Washington, DC: Federal Highway Administration.

FHWA. n.d. “Corrosion and Publications.” (web page). https://highways.dot.gov/research/laboratories/coatings-corrosion-laboratory/corrosion-coating-publications, last accessed October 21, 2021.

Fitz-Gerald, J. M., S. R. Agnew, W. Moffat, S. R. Sharp, J. S. Gillespie, D. R. Becker, R. Liu, and A. W. Runion, Jr. 2019. *Innovative Coating Removal Techniques for Coated Bridge Steel*. FHWA/VTRC 20-R1. Washington, DC: Federal Highway Administration.

Liu, R., and A. W. Runion, Jr. 2020. *Coating Performance on Existing Steel Bridge Superstructures*. Report No. FHWA-HRT-20-065. Washington, DC: Federal Highway Administration. https://www.fhwa.dot.gov/publications/research/infrastructure/structures/bridge/20065/20065.pdf.

Contact

Frank Jalinoos

frank.jalinoos@dot.gov

Disclaimer

The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this presentation only because they are considered essential to the objective of the presentation. They are included for informational purposes only and are not intended to reflect a preference, approval, or endorsement of any one product or entity.