Research at a Glance

Technical Brief

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NJDOT Corrosion Study on Steel Structural Members

Research Problem Statement

New Jersey has over 6,800 bridges, of which more than half have steel superstructures. The state's coastal geography exposes many bridges to airborne chlorides from the ocean, while high traffic volumes, due to its dense population and frequent winter precipitation, necessitate the application of de-icing salts. These combined environmental and operational factors increase the susceptibility of New Jersey's steel bridges to corrosion, which reduces the cross-sectional area of steel members, diminishing their load-carrying capacity and altering stress distributions, leading to unexpected deflections, fatigue, or even localized failures. Corroded elements can also affect the serviceability and longevity of a bridge, creating hazards for both traffic and maintenance personnel.

Fortunately, nearly all steel components are protected by some kind of coating and major efforts are made on maintaining the steel members of bridges, including a condition evaluation that is performed every 2 years. When steel coatings are well maintained, the service lives of the parent members are virtually unlimited.

Research Objectives

This project focused on enhancing these protection efforts by evaluating the performance of steel coatings and weathering steel bridges and providing recommendations on maintenance activities based on service life estimations.

Methodology

NJDOT's bridge paint inspection database, containing results for 1,308 bridges from 2012–2022, served as the primary dataset. Paint condition was rated on a 0–10 scale based on percent area exhibiting rust, and categorized by bridge element (fascia beam, interior beam, bottom flange, beam end, bearing, etc.) and exposure category. Deterioration curves were developed by fitting quadratic or linear regression models between paint condition and coating age.

	Code Description		Description for Weathering Steel
0	100% Rust	0	100% Failed Oxide Protective Layer
1	50-100% Rust	1	50-100% Failed Oxide Protective Layer
2	33-50% Rust	2	33-50% Failed Oxide Protective Layer
3	16-33% Rust	3	16-33% Failed Oxide Protective Layer
4	10-16% Rust	4	10-16% Failed Oxide Protective Layer
5	3-10% Rust	5	3-10% Failed Oxide Protective Layer
6	1-3% Rust	6	1-3% Failed Oxide Protective Layer
7	0.3-1% Rust	7	0.3-1% Failed Oxide Protective Layer
8	0.1-0.3% Rust	8	0.1-0.3% Failed Oxide Protective Layer
9	.03-0.1% Rust	9	.03-0.1% Failed Oxide Protective Layer
10	0-.03% Rust	10	0-.03% Failed Oxide Protective Layer

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In addition, 26 uncoated weathering steel bridges were field-inspected. Chloride surface tests, tape adhesion tests, and patina sampling were conducted. Laboratory analysis (ion chromatography and FTIR spectroscopy) characterized corrosion products and chloride concentrations.

Results

Results showed strong correlation between deterioration rate and environmental exposure. In mild rural environments (Cat. 01), coatings typically lost one condition point every 10 years (slope $\approx$ –0.1), while marine severe exposures (Cat. 3B) saw deterioration rates more than double (–0.20 to –0.30). Bearings and beam ends deteriorated fastest, reflecting their higher moisture and salt exposure. Route-level analysis found bridges on NJ Route 35 performed worst, consistent with their coastal exposure.

Statistical comparisons of inorganic (IEU) and organic (OEU) zinc primer systems indicated small differences, with IEU systems providing, at most, about five additional years of service life.

Maintaining coating condition ratings above 7 ($\approx$1% corrosion) was identified as critical to prevent steel deterioration. When condition drops below 7, spot- or over-coating interventions are recommended.

From deterioration slopes, service-life estimates were calculated for key elements:

- Interior beams: 25 years (Cat. 01 & 3A), 17 years (Cat. 02), 13 years (Cat. 3B)
- Beam ends: 20, 16, and 12 years respectively
- Bearings: 15, 13, and 9 years respectively

Most of the inspected weathering steel bridges were in good condition, particularly those in rural or mildly industrial locations. Poor performance occurred near coastlines and overpasses exposed to heavy de-icing salts, where moisture retention led to coarse, flaking patinas. Adhesion testing proved effective for assessing patina quality, while chloride measurements were inconsistent indicators.

Statistical analysis of weathering steel inspection data confirmed low deterioration rates (slopes –0.016 to –0.021 per year) for well-performing structures, increasing threefold for newer bridges lacking mature patinas. Areas prone to prolonged wetness (e.g., beam ends and bearings) showed deterioration after 20–30 years, requiring periodic over-coating. Properly maintained webs and flanges, however, frequently exceed 50 years of service life without intervention.

Recommendations

- Maintain coating condition ratings above 7 by scheduling spot-coating every 10–20 years (depending on exposure) and over-coating every 10–30 years for weathering steel beam ends.
- Conduct annual washing of bridges in marine or salt-exposed regions.
- Improve bridge detailing to eliminate joints and moisture traps; divert water (e.g., gutters) where possible; extend scuppers at least 12 inches below the bottom flange.
- Use tape adhesion testing for routine weathering steel inspection over chloride testing as a primary assessment tool.
- Continue use of three-coat zinc-rich systems (IEU) as standard; evaluate two-coat systems only under controlled applications.

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