

Weathering Steel and Corrosion Protection of Steel Bridges

Corrosion is the main long-term enemy of steel bridges, and the owner has two basic strategies against it: let a weathering-grade steel protect itself with a stable oxide patina, or put a barrier or sacrificial coating between the steel and the environment. This course covers both. It explains how the weathering steel patina forms and why it fails in wet, salty or sheltered conditions; summarizes the siting, detailing and maintenance guidance in FHWA Technical Advisory T 5140.22 (1989) and the July 19, 2023 FHWA memorandum on follow-up actions for uncoated weathering steel bridges issued after the Fern Hollow Bridge collapse; compares zinc-rich paint systems, thermal-spray metalizing and hot-dip galvanizing using the FHWA Steel Bridge Design Handbook corrosion-protection volume; and closes with inspection and preservation of protection systems using the FHWA Bridge Preservation Guide (2018). Numerical guidance quoted in the course is attributed to its source; worked numbers in the examples are illustrative and computed for this course, not from a real bridge.

Learning objectives

- Explain how weathering steel patina forms
- Identify environments where it performs poorly
- Compare coating systems
- Inspect and maintain protection systems

Why steel bridges corrode

Steel corrodes when iron, oxygen and an electrolyte (water) are all present. The rate is controlled mostly by how long the surface stays wet and what is dissolved in the water. The FHWA Steel Bridge Design Handbook corrosion volume (Vol. 19) lists the key variables for a bridge site as **time of wetness**, **salt** (airborne marine salt and deicer runoff), **other contaminants**, **temperature**, **wind direction** and **anticipated traffic**, since heavier traffic tends to bring heavier deicer use and more airborne spray.

The handbook groups macro-environments as mild (rural), industrial, moderate and severe (marine), and notes that the most important design breakpoint is between moderate and severe. It also warns that the micro-environment, meaning the specific spot on a specific member, often matters more than the region. Steel under a leaking joint in a mild climate can corrode like steel at the beach.

Two strategies: patina or coating

Owners protect steel superstructures in one of two ways:

- **Uncoated weathering steel (UWS).** A low-alloy steel whose rust layer becomes dense and adherent under wet-dry cycling, slowing further corrosion to a very low rate. No initial paint and no repainting, if the site and details suit it.
- **Coated steel.** Carbon or weathering steel protected by a paint system (today usually zinc-rich based), a thermal-spray metal coating, or hot-dip galvanizing. These systems need surface preparation, quality control, and eventually maintenance or recoating.

Many bridges mix the two: weathering steel girders with painted ends under joints, galvanized or metalized bearings and railings, and painted fascia or splash-zone steel. Choosing well means matching each part of the structure to its exposure.

The protection system is part of the structure

A coating or patina is not cosmetic. When it fails locally, section loss follows, and section loss changes load ratings. The Fern Hollow Bridge collapse in Pittsburgh on January 28, 2022 involved an uncoated weathering steel rigid frame whose legs, per the NTSB interim findings quoted by FHWA, had experienced significant deterioration and section loss from continual accumulation of water and debris that prevented the protective patina from developing. FHWA's July 2023 memorandum turned those lessons into required actions for State DOTs, covered later in this course. The common thread through every source in this course is the same: **keep water, salt and debris off the steel, and follow up on what inspections find.**

How the weathering steel patina forms

Weathering steels are low-alloy structural steels. The FHWA Steel Bridge Design Handbook corrosion volume describes them as carbon steel with small additions of **copper, chromium, nickel and silicon**, produced over the years in various proprietary chemistries. Those small additions change the character of the rust. On ordinary carbon steel, the oxide layer is porous and tends to spall, so fresh steel is continually re-exposed and corrosion continues at a roughly steady rate. On a weathering steel exposed to the right conditions, the oxide layer becomes dense and tightly adherent and acts as a barrier between the base metal and the environment.

The key phrase in the handbook is *cyclic wet/dry exposure*. The surface must get wet, from rain or dew, and then dry out. Repeated cycles build the protective layer. The handbook is explicit that "a true wet-dry cycle is necessary for the proper formation of protective corrosion films on weathering steel," and that details which remain almost constantly wet will not form the film and "will continue to corrode during their lifetime." It is equally explicit that "excessive moisture or the presence of salt will disrupt this process and result in a structure that corrodes at an unacceptable (much higher) rate."

This explains the shape of the corrosion curves the handbook presents. In the first year or two, weathering steel loses metal at a rate lower than, but similar to, carbon steel. After that, in rural and industrial environments, the weathering steel curve flattens toward what the handbook calls a negligible ambient rate, while the carbon steel curve keeps climbing. In marine environments the weathering steel curve bends but does not fully flatten, which means section loss continues for the life of the structure. The handbook states that "the flattening of the corrosion curve determines the acceptability of a particular environment for bare weathering steel."

Shop blasting

Weathering steel girders are normally abrasive-blasted in the shop even when they will not be painted. The handbook gives the reason: blasting removes mill scale, which can promote corrosion of the base steel, and allows uniform initial formation of the patina. A girder delivered with patchy mill scale will weather unevenly, with streaks and blotches that can persist for years and make later inspection harder.

Grades

FHWA T 5140.22 (1989) describes these steels as supplied under AASHTO M270 (ASTM A709) in grades 50, 70 and 100, with the letter "W" following the grade where enhanced atmospheric corrosion resistance is wanted. The handbook adds that the high performance steel (HPS) grades 70 and 100 were designed as weathering grades with corrosion resistance essentially

equal to that of ASTM A588 weathering steel. Grade designations in A709 have evolved since those documents were written, so specify grades from the current edition adopted by your owner.

What good and bad patina look like

Inspectors are the people who decide, year after year, whether a weathering steel bridge is actually weathering. T 5140.22 asks owners to develop inspection guidelines that "illustrate the difference between the desired oxide coating and excessive rust scaling." The descriptions below are the general characteristics inspectors use; your agency's inspection manual should have photographs for calibration.

- **Protective patina.** Uniform in color, typically developing from orange-brown when new toward a darker brown to purple-brown over years of exposure. The surface is tight and fine-textured. Rubbing or light tapping removes little or nothing.
- **Granular or dusty rust.** A coarser, powdery surface that comes off on a glove. It can indicate the patina is still developing, or that conditions are marginal. It warrants watching, especially if it persists after several years in service.
- **Flaking and laminar rust.** Flakes larger than about a fingernail, sheets or layered "laminar" rust that can be pried off in plates. This is not a protective layer. It signals sustained wetness or salt exposure and active section loss underneath.
- **Pack rust.** Rust forming between faying surfaces, at plate overlaps or under connection plates. Because rust occupies much more volume than the steel it came from, pack rust can bow plates, pop rivets or bolts, and distort members.

Location tells you as much as appearance. Patina on a fascia web that sees sun and rain is expected to look different from the patina on an interior bottom flange that is shaded and collects condensation. The handbook points out that bottom flanges break down early on all steel bridges because preferential condensation gives them a higher time of wetness than the rest of the member. When the same type of flaking rust shows up only under a joint, only above a truck lane, or only where debris piles up, the cause is the micro-environment, and the fix is to change that micro-environment.

Measuring rather than guessing

Where appearance suggests active loss, measure. Ultrasonic thickness gauges and calipers on cleaned spots give remaining thickness that can be compared with plan dimensions and fed into a load rating. FHWA's 2023 presentation on the UWS memorandum points to cleaning per MBE Article 4.3.5.2 before documenting deterioration, because rust scale hides the real surface. A layer of flaking rust can look like the plate has grown thicker when in fact it has lost metal.

Corrosion-rate benchmarks from the handbook

SBDH Vol. 19 gives several quantitative benchmarks that are useful when judging whether a site or detail is suitable for bare weathering steel:

- "Properly functioning weathering steel will corrode at a steady-state rate less than **0.3 mils per year** (7.5 microns per year). Corrosion in excess of this rate indicates that weathering steel should not be used bare at that location."
- Improperly located or detailed weathering steel structures "have shown average corrosion rates of up to **0.004 inches (4 mils) per year per exposed side**," and pitting can go much deeper than the average.
- A weathering steel bridge with an ambient rate below 1 mil per year can show about four times that rate on bottom flanges directly above truck travel lanes, because traffic throws a plume of salty spray.

The handbook also reproduces 1960s ASTM exposure data for carbon steel. Two-year section loss ranged from 9.2 μm at Phoenix, Arizona (rural) to 1,070 μm at Kure Beach, North Carolina, 24 m from the shore. The same Kure Beach site at 240

m from the shore showed 292 μm over two years. Distance from the surf, elevation and local wind all matter enormously, which is why the handbook says there is no specific map defining the boundary between moderate and severe sites.

Illustrative arithmetic

The following numbers are illustrative, computed for this course. Consider a 0.75 in. bottom flange. At the 0.3 mil per year benchmark, 75 years of exposure on two faces removes $2 \times 75 \times 0.0003 = 0.045$ in., about 6% of the thickness. At the 4 mil per year per side rate reported for poorly sited structures, the same 75 years would remove $2 \times 75 \times 0.004 = 0.60$ in., which is 80% of the flange, and the bridge would need major repair long before that. Even 20 years at the higher rate removes 0.16 in., more than 20% of the flange. The difference between a good and a bad site is not a matter of appearance. It is the difference between a flange that lasts the service life and one that governs the load rating within a generation.

T 5140.22: where weathering steel struggles (environment)

FHWA Technical Advisory T 5140.22, *Uncoated Weathering Steel in Structures*, was issued October 3, 1989, following a 1988 FHWA Weathering Steel Forum. It is still listed among FHWA's active technical advisories and is the document FHWA's 2023 memorandum points back to. Its guideline section says that if a proposed structure is at a site with any of the listed environmental or location characteristics, uncoated weathering steel "should be considered with caution and a study of both the macro-environment and micro-environment by a corrosion consultant may be required." Note the wording: the advisory does not ban weathering steel in these settings. It shifts the burden to the designer to show the site is suitable, and its discussion adds that "if serious doubt remains after applying the guidelines in the selection process, then engineering judgment should lean towards coated steel."

Marine coastal areas

Salt-laden air from the Atlantic, Pacific and Gulf coasts can be carried inland by prevailing winds, and the effect depends on wind direction, distance from the shore and local topography. The advisory says suitability can be judged from the behavior of neighboring metal and concrete structures and, when needed, by measuring average daily airborne chloride with the ASTM G92 "wet candle" method. It reports that the UK Department of Transport standard BD 7/81 suggested not using uncoated steel when chloride exceeds 0.1 mg/100 cm²/day, but that US corrosion rates are substantially lower, presumably because of shorter times of wetness. Its conclusion: "it is estimated that weathering steels can be used safely in the United States at chloride levels up to at least **0.5 mg/100 cm²/day**, average." It cites the Kure Beach 250 m lot, where 30-year average chloride was about 1.0 mg/100 cm²/day: boldly exposed flat panels performed satisfactorily there, but performance "may be marginal for actual structures containing crevices and sheltered areas."

Frequent high rainfall, high humidity or persistent fog

Condensing conditions produce long periods of wetness. The advisory recommends evaluating expected time of wetness with ASTM G84 and says that if the yearly average time of wetness exceeds **60 percent**, caution should be used with bare weathering steel. It names parts of the Pacific Northwest west of the Cascades as an example.

Industrial areas

Chemical fumes can deposit on and attack steel surfaces. The advisory relays the UK guidance not to use uncoated weathering steel where sulfur trioxide exceeds 2.1 mg/100 cm²/day average. SBDH Vol. 19 adds a modern perspective: the industrial classification "has become less important in recent years" as clean stack gas regulations reduced airborne pollutants, but it still matters directly downwind of known corrosive process streams.

T 5140.22: where weathering steel struggles (location and geometry)

Tunnel-like grade separations

The advisory describes the "tunnel effect": a narrow depressed roadway between vertical retaining walls, narrow shoulders, minimum vertical clearance and deep abutments. Together these trap the salty spray thrown up by traffic, so it settles on the steel instead of dispersing. The advisory says uncoated weathering steel should be avoided in these situations where winter deicing salt use is significant. It adds a useful note: where the vertical walls are limited to deep abutments, with short or no approach retaining walls, there was no evidence of salt spray causing excessive corrosion. The problem is the long, walled-in cut, not every overpass.

SBDH Vol. 19 reinforces this. Truck traffic at highway speed "creates a significant water (and salt, if applied) plume to a height well above traffic," and grade separations with only a few feet of clearance above treated roads see significant airborne salt all winter. There is no research-based plume height to design to, so this is a judgment call based on clearance, truck volume and salting practice.

Low-level water crossings

Spray and condensation from water close beneath the bridge keep the steel wet. T 5140.22 recommends a clearance to the bottom flange of **at least 10 ft over sheltered, stagnant water and at least 8 ft over running water**. Below those clearances, the advisory's caution applies.

Deicing salt in general

The handbook observes that, away from the coast, the moderate-versus-severe decision becomes a question of how often deicers are applied and whether the runoff can realistically be kept off the steel. In heavily salted northern areas, it says the default position must be a high-durability protection system unless the bridge is painstakingly detailed to avoid all contact with salty runoff and splash. In the middle latitudes, where salting is inconsistent, the decision must be made site by site. The handbook also notes that the frequency of salt application rose dramatically over the two decades before it was written, as agencies adopted bare-pavement winter policies, and advises designers to assume corrosive deicers will continue to be used.

A site screening checklist

Pulling these points together, a designer considering bare weathering steel can screen a site with questions such as:

1. Is the site within several miles of salt water, or exposed to prevailing onshore winds? If so, has airborne chloride been estimated or measured?
2. Does the site have persistent fog, high humidity or frequent rain such that time of wetness may exceed 60 percent?
3. Is the bridge downwind of a known industrial fume source?
4. Is it a grade separation over a heavily salted, high-truck-volume route with long retaining walls and minimum clearance?
5. Is the low steel within 10 ft of stagnant water or 8 ft of moving water?
6. How do nearby existing steel and concrete structures look?

Any "yes" calls for the closer study the advisory describes, or a decision to coat.

Detailing: keep water off the steel

Siting is half the problem. The other half is detailing, and here T 5140.22 and the handbook agree that the guidance applies to coated and uncoated steel alike, but is most critical for uncoated weathering steel. The advisory calls controlling roadway drainage "the first line of defense against localized corrosion."

Joints

The advisory says that to the extent possible, bridge joints should be eliminated, noting that jointless steel bridges had been used to lengths of 400 ft and more, and up to 1,600 ft with joints only at the ends, with no problems identified from the lack of joints. It observes that "virtually every bridge with joints has problems (corrosion, rideability, maintenance) attributable to the joint," and that "obtaining a permanent water-tight bridge joint is an elusive goal." Its design assumption is blunt: **joints will leak**, and drainage will reach the steel. So:

- Coat all steel within a minimum of **1.5 times the girder depth** of the joint.
- Control the water that passes through, for example with a trough beneath the joint.

The handbook, written later, adds a caution about troughs: experience shows they tend to fail or clog with debris, so it recommends closed or sealed joints over open joints with troughs, fewer joints through continuity, integral abutments where feasible, and sealed modular joints in place of multiple single compression seals.

Drip bars

Drip bars on the bottom flange can intercept water running along the flange. The advisory warns that welding any attachment to a tension flange should be considered only after analyzing its effect on fatigue life. The handbook adds that drip bars are effective only for low flows such as condensation.

Scuppers and downspouts

The advisory recommends maximizing scupper spacing within hydraulic design limits, so each scupper carries enough flow to flush itself, and keeping downspout discharge off the steel. It warns that flat runs of pipe, elbows and separating connections often create more problems than they solve, and that drain pipes should not run through closed box sections where leaks can go undetected. The handbook is more pessimistic still: drains and scuppers "have traditionally been undersized" and often have a useful life of only the first few years, so designers should assume steel below the deck will not be kept dry by them. Pipes should have steep slopes and no sharp bends.

Fascia girders

The advisory found no evidence that coating an entire fascia girder adds to the service life of an otherwise uncoated bridge, and noted it creates maintenance and appearance problems. That does not contradict coating fascias that see coastal wind-driven salt; it means coating the fascia for its own sake is not a durability measure.

Detailing: traps, boxes, overlaps and staining

Water and debris traps

The handbook says water and debris traps "should be avoided at all costs," calling them "the traditional breeding ground for rapid corrosion of structural steel." Typical traps include horizontal plates, pockets where members meet, bearing areas boxed in by stiffeners and flanges, and anywhere birds nest. The advisory adds that small copes and drain holes plug easily and

should not be relied on for drainage. Inaccessible details that cannot be inspected or maintained are, in the handbook's words, "poor design practice and must be avoided."

Box members

T 5140.22 says boxes too small to inspect should be hermetically sealed or given weep holes for drainage and air circulation, and that larger boxes need locked, hinged covers or screens over access holes, positive drainage and ventilation. The handbook's experience is that welded box girders "cannot be made watertight for the long term," so they should have drain holes at low points and access hatches. It notes the common practice of painting box interiors with white topcoat to aid inspection.

Overlapping surfaces and pack rust

Water flowing over an overlapping joint can be drawn in by capillary action and form pack rust. The advisory says faying surfaces of non-slip-critical bolted joints and other overlaps exposed to runoff should be painted or sealed. For slip-critical bolted splices, it says rust pack should not occur when bolts are spaced per AASHTO specifications. The handbook also recommends avoiding built-up and back-to-back members, which are impossible to maintain, and using durable caulking where they cannot be avoided.

Dissimilar metals

Direct contact between dissimilar metals such as steel and aluminum, steel and stainless steel, or steel and bronze in a wet environment causes accelerated corrosion of the more active metal. Isolate them.

Staining of concrete

Runoff from weathering steel leaves dark, uneven stains on piers and abutments, especially during the first years. T 5140.22 lists three mitigations: wrap substructure units during construction, have the contractor remove staining with a commercial solvent after construction, or coat or seal the concrete. Staining is an appearance issue, but it is one that communities notice, so address it in the plans.

Edges

For coated steel, the handbook notes that edges show coating breakdown before flat surfaces, which is why good practice includes hand "striping" of edges and complex surfaces before the full coat.

Coating systems: from lead alkyd to zinc-rich

For decades, SBDH Vol. 19 explains, the dominant bridge coating was several coats of lead-containing alkyd paint, applied over intact mill scale with little or no surface preparation. It was cheap and easy, and it worked as long as periodic maintenance painting was done. In the 1970s, the benefits of abrasive blasting to remove mill scale became well known, and full blast cleaning became standard. That made possible the high-performance systems used today, mostly multicoat systems built around a **zinc-rich primer**. Many older bridges still carry lead-based paint, which is why maintenance repainting usually requires containment, worker protection and hazardous-waste disposal, and why T 5140.22 mentions cases where disposal costs were so high that a structure was abandoned or replaced.

Surface preparation

For new steel to be painted, the handbook says shop preparation is generally an **SSPC SP-10 near-white metal blast**, with a specified surface profile, generally 2 to 4 mils, compatible with the primer. Surface preparation is the single largest driver of coating life: the handbook contrasts high-performance coatings over SP-10 with maintenance coatings over SSPC SP-3 (power-tool cleaning that leaves adherent old paint and rust) as the two typical options owners face.

Zinc-rich primers

Zinc-rich primers carry a heavy loading of zinc dust. Because zinc is more active than steel, it corrodes preferentially and protects the steel at small breaks in the film, which is called cathodic or sacrificial protection. Primers are either inorganic zinc (IOZ), with a silicate binder, or organic zinc (OZ), with an epoxy or urethane binder. The handbook reports that a 1996 TRB survey found 42 of 54 bridge agencies specifying zinc-rich primers for new construction, and that ethyl silicate inorganic zinc is the usual shop primer when the shop primes and topcoats go on in the field after erection.

The three-coat system

Early zinc-rich systems in the 1970s used vinyl topcoats, which were phased out as solvent regulations tightened. The predominant approach is now a three-coat system:

1. **Zinc-rich primer**, providing the primary corrosion protection.
2. **Epoxy midcoat**, an excellent moisture barrier that adds physical protection to the primer.
3. **Polyurethane topcoat**, a weatherable barrier with long-term color and gloss retention and resistance to chalking from sunlight.

Some agencies use waterborne acrylic topcoats instead, and a few use all-waterborne acrylic systems on bridges without heavy salt exposure.

Faying surfaces at bolted splices

Slip-critical bolted connections depend on friction between the plies. The handbook notes that a full three-coat system on each faying surface could put roughly 20 mils of paint between plates, which may slip and creep over time. So a single coat of inorganic zinc, tested and qualified for slip and creep, is usually applied in splice areas.

Specifying and qualifying coatings

The handbook cautions that performance among generically similar paints varies widely, so specifying "by generic type or using an 'or equal' approach can lead to disappointing performance results." It points to AASHTO's National Transportation Product Evaluation Program (NTPEP) as a national clearinghouse for bridge paint performance data, the AASHTO/NSBA Steel Bridge Collaboration guide specification for shop painting, and SSPC's *Good Painting Practice* for application quality.

Metalizing and galvanizing

Thermal-spray metalizing

Metalizing uses modified flame or electric-arc equipment and compressed air to melt zinc, zinc/aluminum or aluminum wire and spray it onto the steel, where it solidifies as overlapping splats forming a sacrificial metal coating. SBDH Vol. 19 states that metalizing "requires at least an SSPC SP-10 abrasive blast cleaning and application of **8 to 12 mils** of thermal sprayed metal (either zinc or zinc/aluminum alloy)," that the industry recommends at least a sealer and often a sealer plus finish coat

over it, and that the system "has demonstrated durability in marine environments." Owners' concerns have been cost, productivity and the industry learning curve.

Hot-dip galvanizing

Galvanizing immerses the whole component in a kettle of molten zinc. The heat forms metallurgically bonded zinc-iron layers beneath an outer zinc layer, giving an adherent, corrosion-resistant coating whose life depends on zinc thickness and the corrosion rate of zinc in the given environment. Historically galvanized steel was hard to paint, limiting appearance to the gray spangled finish, but the handbook says topcoated galvanizing is now commonplace. The two main limits for bridges are **kettle size and availability**, since the member must be fully immersed, and **transportation cost**. The handbook mentions kettles in North America between 50 and 80 ft long. Galvanizing and metalizing are also common for elements that are hard to paint in place, such as gratings, bearings and railings.

Expected life

SBDH Vol. 19 summarizes service-life data as follows:

System	Marine / salt-rich	Less severe salt-containing
3-coat zinc-rich (e.g., ethyl silicate IOZ) over SP-10	15 to 20 years	about 25 years
Metalized zinc or zinc/aluminum	at least 20 to 25 years	up to 40+ years
Overcoating sound, well-adhered existing paint with minor rust	7 to 10 years documented; failures in under 3 years where adhesion was poor and rusting significant; best FHWA-tested overcoats began failing after about 2 years in marine or salt-laden drainage exposure	

The handbook notes that zinc-rich systems applied in the mid-to-late 1970s on bridges in Iowa, West Virginia, Louisiana and other states were then just beginning to need some maintenance painting, which supports these figures.

Comparing options: first cost and life-cycle cost

On first cost, weathering steel looks like the obvious choice. SBDH Vol. 19 cites an FHWA-sponsored study putting the median cost of shop coating at about 7% (primer only) and 11% (three coats) of the fabricated girder cost, while the historical premium for weathering grade over carbon steel has been around 4%. But the handbook lists the offsets: weathering steel girders still need shop blasting to remove mill scale, and girder ends at non-integral joints still need painting for 1.5 times the girder depth.

The handbook recommends a life-cycle cost comparison that accounts for material cost, shop preparation and coating, expected coating life in the actual environment, maintenance costs and timing, and the structure's service life, often using an equivalent uniform annual cost (EUAC) approach. It emphasizes that assumed coating life strongly affects the answer, and that overcoating should be assumed only where it has a reasonable chance of long-term success.

Illustrative comparison

All numbers in this example are illustrative, invented for teaching; they are not from the handbook or a real project. Suppose a girder line has 20,000 ft² of steel surface and a 75-year service life. Option A is painted carbon steel: initial three-coat system at \$10/ft² (\$200,000), with full blast-and-repaint at \$30/ft² at years 25 and 50 (\$600,000 each). Option B is weathering steel with painted ends: a steel premium and end painting totaling \$60,000, plus repainting the 10% of surface near joints at years 25 and 50 (\$60,000 each), plus periodic washing and debris removal at \$5,000 every 2 years (about 37 events,

\$185,000). Undiscounted, A totals \$1.4 million and B about \$365,000. Discounting narrows the gap but rarely reverses it at a suitable site.

Now move Option B to an unsuitable site, such as a tight grade separation over a heavily salted interstate. If the girders lose section above the truck lanes and need flange repair and full coating at year 20, B's costs can exceed A's, and the bridge may carry a reduced load rating in the meantime. The point of the example is not the numbers; it is that the decision depends on the site, the details and the owner's maintenance capacity.

Fern Hollow and the July 2023 FHWA memorandum

The Forbes Avenue Bridge over Fern Hollow in Pittsburgh was a three-span (138 ft-4 in., 166 ft-0 in., 138 ft-4 in.) uncoated weathering steel rigid frame, 442 ft-8 in. long, built in 1972 to 1973. It collapsed completely on January 28, 2022. According to FHWA's memorandum, four vehicle occupants were injured, two seriously, and a National Highway System route was out of service for 11 months. The bridge was fracture critical, in poor condition with annual inspections, and posted at 26 tons, per FHWA's presentation on the memo.

On May 18, 2023, NTSB issued an interim report (NTSB/HIR-23-07) with three findings, as quoted by FHWA: the frame legs had significant deterioration and section loss, documented in inspection reports, caused by continual accumulation of water and debris that prevented the protective patina from developing; incomplete maintenance (identified but not done) was not unique to Fern Hollow among Pennsylvania bridges examined; and owners nationwide need to make sure follow-up actions on water and debris accumulation on weathering steel bridges are completed. FHWA noted that the bridge was not in a marine, high-rainfall or industrial environment, but predated T 5140.22 and had deck drainage that ran onto the legs and numerous debris traps, and that maintenance actions identified over an 11-year period before the collapse were not performed. The interim report did not determine probable cause.

Required actions

On July 19, 2023, FHWA's Office of Bridges and Structures directed, under 23 CFR 650.313 and 650.315, that State DOTs:

1. Identify all bridges in their inventory, regardless of owner, with uncoated weathering steel components in the primary load path.
2. Sort them into **Group 1**: (i) bridges with UWS components in the substructure, or rigid frames, with a condition rating of 4 or less for the component containing the UWS; (ii) bridges with UWS nonredundant steel tension members in the superstructure with superstructure rating 4 or less; and (iii) NHS bridges with any UWS National Bridge Element (except railings) with quantities in Condition State 4. All others are **Group 2**.
3. Report Group 1 structure numbers by October 31, 2023.
4. By December 31, 2024, for each Group 1 bridge, confirm recommended work addressing UWS deficiencies was completed and that the load rating reflects documented deterioration and completed work; where work was not done or cannot be confirmed, make sure deterioration is documented well enough to support a load rating, do a one-time special inspection if it is not, and update the load rating.
5. For Group 2, at the next scheduled inspection, confirm that the preventive maintenance and preservation activities described in T 5140.22 are identified and communicated to the appropriate authority.

The memo's lesson for engineers is that a weathering steel bridge is not maintenance-free. It is *painting*-free, at best, and it depends on drainage control and debris removal being done.

Inspecting protection systems

T 5140.22 asks owners to "implement inspection procedures that recognize the unique nature of uncoated weathering steel and the conditions resulting from excessive corrosion damage." For both coated and uncoated steel, an inspection of the protection system should look at:

- **Joints and the steel beneath them.** Leaking seals, clogged troughs, staining or rust streaks down the web, and the condition of the painted zone at girder ends.
- **Drainage.** Scupper and downspout condition, disconnected or corroded-through pipes spraying onto steel, and runoff paths across bearings and pier caps.
- **Debris and nests.** Accumulations on bottom flanges, bearing seats, cross-frame connections and inside boxes. Debris holds moisture and salt against the steel.
- **Patina quality (UWS).** Tight versus flaking or laminar rust, and where each occurs.
- **Coating condition (painted steel).** Chalking, checking, blistering, peeling, undercutting from edges, and rust breakthrough, with an estimate of the percentage of area affected.
- **Section loss.** Cleaned and measured where flaking or pack rust appears, so the load rating can account for it.
- **Pack rust** at connections and overlaps, and any distortion it causes.
- **Vegetation** that shades steel and prevents drying.

Under element-level inspection, coating condition is recorded as a protective-system element separate from the steel element it protects, so that coating deterioration is visible in the data before section loss starts. The FHWA Bridge Preservation Guide suggests tracking measures such as the percent of steel protective coating elements in condition state 2 or better.

Writing actionable findings

The NTSB interim findings centered on maintenance identified but not done. Inspection findings drive action only if they are specific. "Clean debris from bottom flanges at Pier 2, both girders, approx. 6 in. deep, flaking rust beneath" can be scheduled and verified. "Debris present" usually cannot. Under the 2023 memo, Group 2 bridges must have their T 5140.22 preservation needs identified and communicated at the next inspection, so the inspection report is where that obligation is met.

Maintaining and preserving protection systems

T 5140.22 lists minimum maintenance actions that should be routine on weathering steel bridges, and that apply equally well to painted steel:

- Divert approach roadway drainage away from the bridge.
- Clean troughs of open (finger) joints and reseal "watertight" joints.
- Maintain deck drainage systems so runoff stays off superstructure steel and substructure units.
- Periodically clean and, when needed, repaint all steel within a minimum of 1.5 times the girder depth from joints.
- Remove dirt, debris and deposits that hold moisture; the advisory notes some agencies hose down bridges on a regular schedule.
- Maintain covers and screens over box access holes to keep out animals and birds.
- Remove nearby vegetation that prevents natural drying.

The preservation framework

The FHWA Bridge Preservation Guide (FHWA-HIF-18-022, 2018) separates preventive maintenance into **cyclical** activities on a set interval and **condition-based** activities in response to inspection findings. Its cyclical examples include cleaning and washing the bridge, cleaning and flushing drains and cleaning joints; it notes cleaning slows deterioration otherwise accelerated by debris, bird droppings and contaminants, and that intervals should change with conditions, for example if pigeons begin nesting. Its condition-based examples include joint seal replacement, joint elimination, drain repair, protective coating of steel, and **spot, zone or full painting** of steel superstructure and substructure elements.

The guide also stresses that preserving a protective element protects the elements beneath it: a sound coating protects the steel beam, and a sound joint protects the beam end, bearing and substructure below. Fixing the joint is often the most effective corrosion repair on the bridge.

Choosing a painting strategy

- **Spot painting** repairs small, localized failures. It suits a sound system with isolated damage.
- **Zone painting** recoats a defined region where the environment is harsher, typically girder ends under joints and bearing areas. SBDH Vol. 19 explains why this works: the most corrosive areas are predictable.
- **Overcoating** applies a compatible coat over sound existing paint after limited preparation. It avoids full removal and, on lead-painted bridges, can defer containment costs, but per SBDH Vol. 19 it should be limited to areas with well-adhered paint and minor rust.
- **Full removal and recoating** blasts to bare metal and applies a new high-performance system. It is the most expensive and the most durable.

Case study: a weathering steel overpass

This scenario is illustrative, invented for teaching. A 1980s two-span weathering steel girder overpass carries a county road over a four-lane interstate in a state that salts heavily. Clearance is 16 ft 6 in. Long cast-in-place retaining walls line both sides of the depressed interstate. There is a strip-seal joint at each abutment and none at the pier.

The latest inspection reports: (1) at both abutments, the strip seals are torn and the painted zones at girder ends are failing, with laminar rust on the bottom flanges and bearing stiffeners; (2) over the interstate travel lanes, interior bottom flanges show flaking rust while the fascia webs have a tight dark patina; (3) debris and pigeon droppings 3 to 4 in. deep on the pier cap and bottom flanges at the pier; (4) a disconnected downspout spraying onto a fascia girder.

Reading the findings. Item 1 is the joint problem T 5140.22 predicts. Item 2 is the tunnel-like, truck-spray condition the advisory and handbook describe; the fascia's better condition reflects sun and air. Items 3 and 4 are maintenance failures of the Fern Hollow kind.

Reasonable actions. Clean, measure and document section loss at bearings and over the travel lanes, and update the load rating if loss is significant. Replace or eliminate the joints, and zone-paint girder ends for at least 1.5 times the girder depth. Consider zone-coating the bottom flanges over the travel lanes. Reconnect or reroute the downspout. Clean the pier cap and flanges, add bird exclusion, and set a cyclical washing interval. Write each as a specific, trackable work item.

Summary

Weathering steel and coatings are both proven tools. Weathering steel works where the steel can dry and salt stays off. Coatings work when surface preparation and application are right and the system is maintained before rust breaks through.

Either way, the bridge depends on the drainage design and on the follow-through between inspection finding and completed work.

Key takeaways

- Corrosion rate is driven by time of wetness and salt; the micro-environment at a detail often matters more than the region.
- Weathering steel forms a protective patina only under wet-dry cycling without significant salt or constant wetness.
- T 5140.22 urges caution for marine coastal areas, high-rainfall/humidity/fog sites, industrial fumes, tunnel-like grade separations and low water crossings (≤ 10 ft over stagnant water, ≤ 8 ft over moving water).
- Paint all weathering steel within 1.5 times the girder depth of a deck joint, and assume joints will leak.
- SBDH Vol. 19: properly performing weathering steel corrodes at a steady-state rate below about 0.3 mil per year; improperly sited or detailed UWS has shown up to 4 mils per year per side.
- The common three-coat system is zinc-rich primer, epoxy midcoat and polyurethane topcoat over an SSPC SP-10 near-white blast.
- Metalizing (8 to 12 mils of thermal-sprayed zinc or zinc/aluminum over SP-10) and galvanizing are durable alternatives with their own limits.
- The July 2023 FHWA memo required States to identify UWS bridges, sort them into Group 1 and Group 2, and complete follow-up actions and load rating updates for Group 1.

References

1. FHWA Technical Advisory T 5140.22, Uncoated Weathering Steel in Structures, 1989
2. FHWA, Steel Bridge Design Handbook, FHWA-HIF-16-002 (multi-volume), 2015
3. FHWA, Bridge Preservation Guide: Maintaining a Resilient Infrastructure to Preserve Mobility, FHWA-HIF-18-022, 2018
4. FHWA, Memorandum: ACTION: Inspection Finding Follow-up Actions for Uncoated Weathering Steel Bridges, J. L. Hartmann, July 19, 2023 (fhwa.dot.gov/bridge/inspection/Memo_July2023_UWS.cfm)
5. FHWA, Steel Bridge Design Handbook: Corrosion Protection of Steel Bridges, FHWA-HIF-16-002 Vol. 19, 2015 (rosap.nhtl.bts.gov/view/dot/49758)
6. NTSB, Improving the Identification, Prioritization, and Completion of Follow-up Actions on Bridges with Uncoated Weathering Steel Components, Interim Report NTSB/HIR-23-07, May 18, 2023 (as summarized in the FHWA July 2023 memorandum)

Study text only; the final quiz is taken online. Verify all references against the edition your agency has adopted.