

Inspecting Steel Superstructures

Steel bridges fail from corrosion, fatigue and fracture. This course focuses inspectors and engineers on where to look on steel superstructures and how to record findings that a load rater can use.

Learning objectives

- Identify corrosion, section loss and coating failure
- Locate fatigue-prone and NSTM details
- Measure and document section loss for rating
- Inspect pins, hangers and connections

Corrosion and section loss

Corrosion concentrates where water and debris collect: beam ends under leaking joints, bottom flanges, bearing areas, and connections. Record **section loss** as remaining thickness and extent — e.g., "web thickness reduced from 7/16 in. to 1/4 in. over 18 in. height and 24 in. length at the north bearing." Clean scale before measuring with calipers or UT thickness gauges. Holes through webs near bearings are a classic shear and bearing concern.

Coatings and weathering steel

Record coating failure and protective-system condition as separate elements (MBEI). For uncoated weathering steel, FHWA Technical Advisory T 5140.22 explains that the protective oxide forms only with wet-dry cycling; persistent wetness, salt spray and deicing exposure lead to continued corrosion. Flaking, laminar or granular rust instead of a tight patina is a warning sign.

Fatigue-prone details

Inspect details known to crack: cover-plate ends (Category E/E'), web gaps at connection plates (distortion-induced fatigue), intermittent welds, back-up bars, plug welds and coped beam ends. Cracks often show as rust bleeding lines in paint. Any crack in a primary tension member must be documented precisely (location, length, orientation, direction of propagation) and reported to the engineer.

NSTMs, pins and hangers

NSTMs such as two-girder systems, truss tension members and pin-and-hanger assemblies require hands-on inspection (23 CFR 650.313(f)). Check pins for wear, corrosion packing and movement; hangers for cracks at pin holes; and frozen pin plates that induce unintended stresses. Bridge files must identify NSTM locations.

Documentation for load rating

- Locate defects by span, girder and distance from bearing.
- Give remaining dimensions, not percentages alone.
- Sketch section loss patterns on flanges and webs.

- Note pack rust distortion at connections and splice plates.
- Flag gusset plate corrosion along the top of chords (debris lines).

These measurements feed directly into MBE evaluation of deteriorated members.

Part A — Learning objectives and how to use this course

By the end of this course you should be able to:

- Explain the main threats to steel bridge superstructures: corrosion and section loss, fatigue cracking, fracture, impact and heat damage, and problems at connections, bearings and pins.
- Plan a steel superstructure inspection, with attention to access, cleaning, lighting and the members that need hands-on inspection.
- Identify fatigue-prone details and describe the crack patterns that develop at them, using the AASHTO fatigue detail categories as a framework.
- Measure and document section loss in a form a load rater can use.
- Explain what a nonredundant steel tension member (NSTM) is and why the NBIS treats NSTM inspection separately.
- Inspect pin-and-hanger assemblies, gusset plates, bearings and coating systems with an understanding of their failure modes.
- Recognize the steel conditions that call for immediate engineering attention or a critical finding under the owner's procedures.

Key references are the FHWA Bridge Inspector's Reference Manual (BIRM), the AASHTO Manual for Bridge Element Inspection (MBEI), the Specifications for the National Bridge Inventory (SNBI), 23 CFR 650 Subpart C (the NBIS), the AASHTO LRFD Bridge Design Specifications for fatigue categories, FHWA's Manual for Repair and Retrofit of Fatigue Cracks in Steel Bridges, FHWA's Guide for Heat-Straightening of Damaged Steel Bridge Members, FHWA Technical Advisory T 5140.22 on uncoated weathering steel, FHWA's gusset plate load rating guidance, and NCHRP Report 406 on redundancy. Your owner's manuals govern where they differ.

Part B — How steel bridges deteriorate

Corrosion

Steel corrodes when it is exposed to oxygen and moisture, and corrosion accelerates sharply when chlorides are present. On bridges the worst corrosion is almost always local: under leaking joints, at beam ends and bearings, along bottom flanges where debris collects, at the waterline of members in streams, and in crevices such as between riveted plates or under bird debris. General uniform rust on a member far from water sources is usually less significant than heavy pack rust or pitting at a beam end. As with concrete, follow the water.

Pack rust (also called crevice corrosion or rust packing) forms between faying surfaces, such as between riveted or bolted plates. Corrosion products occupy more volume than the steel they replace, so pack rust can bend plates, pop rivets and bolts, and distort connections. Record its location and the visible distortion.

Fatigue

Fatigue cracks start at points of high stress concentration under repeated live-load cycles, typically at welds and at abrupt changes in geometry. They can grow slowly for years and then lead to fracture if not found. Two broad sources are

recognized: **load-induced fatigue**, where the primary stress range from traffic at a poor detail drives the crack, and **distortion-induced fatigue**, where secondary out-of-plane deformation, for example at a connection plate welded to a web but not attached to the tension flange, creates high local stress in a short web gap. Distortion-induced cracking is very common on older welded girders.

Fracture

Fracture is the sudden failure of a member, usually starting from a crack or a flaw, and it is most likely in cold temperatures in steels with lower toughness. Fracture-critical design and fabrication requirements were introduced in the late 1970s because of fractures in service. A fracture in a nonredundant tension member can lead to collapse, which is the reason for the NBIS NSTM provisions.

Mechanical damage

Vehicle and vessel impacts bend, gouge, tear and crack steel members. Fire can soften and distort steel and change its properties. Damage sites also become places where corrosion and fatigue start.

Restraint and movement problems

Frozen bearings, closed expansion joints and corroded pin-and-hanger assemblies cannot accommodate movement, which induces unplanned forces and can crack members or connections. Many bearing and hanger problems are really corrosion problems.

Part C — Planning the inspection

Steel inspection quality depends on getting close. Many fatigue cracks are hairline and cannot be seen from the ground or even from a few feet away. Plan for:

- **Access:** snooper truck, lift, rigging, catwalks, or rope access as appropriate. NSTMs require hands-on inspection, and the NBIS defines hands-on as inspection within arm's length with visual and, as needed, nondestructive evaluation techniques (23 CFR 650.305).
- **Cleaning:** wire brushes and scrapers to remove debris and loose rust at suspect areas, consistent with owner rules on lead-based paint and environmental protection.
- **Lighting:** a strong flashlight held at a low angle reveals cracks and pitting.
- **Tools:** calipers, ultrasonic thickness gauge, pit gauge, straightedge, magnifier, mirror, tape, crack-width card, and dye penetrant or magnetic particle kits where the owner uses them in the field.
- **Preparation:** list the fatigue-prone details, NSTMs, pins and gusset plates from the plans and prior reports so none is missed.
- **Safety:** fall protection, traffic control, rail or navigation coordination, lead exposure controls, and confined space procedures for box members.

Write down the access actually used. A reader needs to know whether a crack was missed because it was not there or because no one got close enough to see it.

Part D — Fatigue-prone details and how cracks show up

The AASHTO LRFD specifications group steel details into fatigue categories from A (best, such as plain rolled material) through B, B', C, C', D, E and E' (worst). Lower categories have lower fatigue resistance. The categories were developed from testing, and the details in Categories E and E' account for many fatigue problems in older bridges. The NBIS extended-interval criteria in 23 CFR 650.311 refer to Category E and E' details, which shows how seriously the regulation treats them. An inspector does not need to memorize every category, but should recognize the details that repeatedly crack.

Details to look for

- **Cover plate ends** on rolled beams and girders, especially where the cover plate end is not welded across or the flange is thick. Cracks start at the weld toe at the end of the cover plate and grow into the flange.
- **Web gaps at connection plates:** transverse stiffeners or diaphragm connection plates welded to the web but not to the tension flange. Out-of-plane distortion causes cracks along the web-to-flange weld or at the end of the stiffener weld.
- **Longitudinal stiffener terminations** and gusset or lateral bracing plates welded to webs or flanges.
- **Intersecting welds** and triaxial-constraint details where welds cross with no relief, a concern raised by fractures on some older girders.
- **Tack welds and repair welds** made without attention to fatigue, including welded attachments added later for utilities or signs.
- **Coped beam ends** and floor-beam connections, where cracks can start at the cope.
- **Plug-welded holes and poorly ground or unfused welds.**

What a crack looks like

A fatigue crack is often finer than a hair. Signs include a thin rust line ("rust bleeding") along a weld toe where moisture has entered a crack, a break or step in the paint along a weld, or a line that persists after cleaning. Do not assume that a rust line is paint failure. Clean the area carefully and inspect with a magnifier and low-angle light. Where an owner allows, dye penetrant or magnetic particle testing can confirm and size a suspected crack.

Recording a crack

Record the member, the exact location (span, girder, distance from a bearing or panel point, top or bottom, which face), the detail at which it starts, the orientation, the length, whether it has extended into a flange or web, and whether it has been arrested by a drilled hole. Photograph with a scale and mark the crack tips with paint or a marker if allowed so growth can be measured next cycle. A crack in a tension flange or a crack in an NSTM should be reported immediately per the owner's procedures; it may be a critical finding.

Common repairs you may see

FHWA's Manual for Repair and Retrofit of Fatigue Cracks in Steel Bridges describes typical approaches, including drilling holes at crack tips to blunt them, bolted splice plates, and, for distortion-induced cracking, either softening the detail (for example removing part of a connection plate) or stiffening it by attaching the connection plate to the flange. When you inspect a repaired location, check whether the crack has reinitiated past the drilled hole or beyond the splice plate.

Part E — Corrosion and section loss: measuring what the load rater needs

A load rater needs remaining section, not adjectives. "Heavy corrosion at beam end" does not support a rating; "bottom flange of G3 at abutment 1 bearing: original 3/4 in, measured 1/2 in minimum over 12 in length, full flange width; web 3/8 in

original, holes through web 2 in x 1 in at 3 in above flange" does.

How to measure

- Clean the area to sound metal where practical and permitted.
- Measure remaining thickness with calipers at accessible edges and with an ultrasonic thickness gauge on faces you cannot caliper. Calibrate the gauge per the manufacturer.
- Use a pit gauge to measure pit depth and note pit density.
- Record the length and width of the affected area and its location relative to bearings, stiffeners and the end of the member.
- Record holes completely through plates with their size and location.
- Sketch the cross-section with original and measured dimensions; original dimensions come from plans or measurements of nearby unaffected areas.

Where section loss matters most

- **Beam ends and bearing stiffeners:** web section loss near the bearing reduces shear and bearing capacity and can lead to web crippling or buckling.
- **Bottom flanges in positive moment regions:** reduces flexural capacity.
- **Truss members and connections:** section loss in tension members and gusset plates, especially near the deck line where debris and salt collect.
- **Pins and hangers:** hidden corrosion can freeze the assembly or reduce section.

Element quantities

The MBEI steel elements use the corrosion, cracking, connection, distortion and coating defects. Assign quantities to condition states using the MBEI definitions and the owner's guidance. Section loss that warrants structural review, and cracking, generally drive quantities to the poorer states. Steel protective coatings are recorded as their own element.

Part F — Nonredundant steel tension members (NSTMs)

The 2022 NBIS replaced the older term "fracture critical member" with **nonredundant steel tension member (NSTM)**, defined in 23 CFR 650.305 as a primary steel member fully or partially in tension, and without load path redundancy, system redundancy or internal redundancy, whose failure may cause a portion of or the entire bridge to collapse. An **NSTM inspection** is a hands-on inspection of such a member, and **hands-on** means inspection within arm's length of the member, using visual techniques that may be supplemented by nondestructive evaluation.

Typical NSTMs

- Two-girder bridges, where the tension flanges and webs of each girder are NSTMs unless redundancy is demonstrated.
- Truss tension members and their connections on two-truss bridges.
- Pin-and-hanger assemblies in two-girder systems.
- Steel cap beams and straddle bents in tension regions.
- Tied-arch ties and hangers.
- Single-box or twin-box girders where redundancy has not been established.

Redundancy is a structural judgment. NCHRP Report 406 describes methods to evaluate superstructure redundancy, and owners may classify members based on refined analysis. The inspection team works from the owner's NSTM list and the

bridge-specific NSTM inspection procedures, which the NBIS requires owners to document.

Intervals

Under 23 CFR 650.311(c) Method 1, NSTMs are inspected at intervals not exceeding 24 months, reduced to not more than 12 months when the NSTM Inspection Condition item is coded 4 or less, and an extended interval of up to 48 months is allowed only when a list of criteria is met (including the NSTM inspection condition coded 6 or greater) and the owner has documented a policy and notified FHWA. Method 2 provides a more rigorous risk-based alternative requiring FHWA approval. Always confirm the interval in the owner's records.

Inspection approach

- Inspect the full length of every NSTM within arm's length, with special attention to welded attachments, cross-frame connection plates, floor-beam connections, cover plates, splices, holes, and areas of corrosion or past repairs.
- Clean suspect areas, and use NDE as required by the bridge-specific procedures.
- Document every crack, gouge, notch and area of section loss, with exact locations.
- Compare with previous cycles using the same location references.

Under 650.313(q), owner critical-finding procedures must at minimum include findings that warrant an NSTM to be rated in serious or worse condition (coded 3 or less) by the NSTM Inspection item. NHS bridges with such findings require FHWA notification within 24 hours of discovery. A crack in an NSTM tension element is reported immediately to the engineer and handled under the owner's procedures.

Part G — Pin-and-hanger assemblies, gusset plates and trusses

Pin-and-hanger assemblies

Pin-and-hanger assemblies suspend a span between cantilevers and allow expansion. They sit under the deck joint, so they are exposed to leakage and corrosion. Corrosion can freeze the pin in the hanger, so the assembly no longer rotates, which induces bending and can crack the hanger or the pin. The 1983 collapse of the Mianus River Bridge in Connecticut involved a pin-and-hanger assembly and led to widespread inspection and retrofit programs.

- Look for corrosion and pack rust between the hanger plates and the web, misalignment, shifted hangers, and bowed or cracked hanger plates.
- Check the pin caps and nuts and any retainer.
- Pins themselves usually cannot be seen; owners may require ultrasonic testing of pins on a scheduled basis.
- Note any retrofit catcher systems and whether they are in contact with the structure.

Gusset plates

Gusset plates connect truss members. Following the 2007 collapse of the I-35W bridge in Minneapolis, which the NTSB attributed to inadequate gusset plate capacity from a design error, FHWA issued guidance on load rating bolted and riveted gusset plates (FHWA-IF-09-014). For inspectors, that means gusset plates get close attention:

- Look for corrosion and section loss, particularly along the edges and at the deck line where debris collects.
- Look for bowing or out-of-plane distortion of plate edges between members, which can indicate high compressive stress or pack rust.
- Record missing or loose rivets and bolts.

- Measure remaining thickness and record locations so a rater can model the connection.

Trusses

Identify tension and compression members from plans. Tension members on two-truss systems are typically NSTMs. Look for section loss, bent members from impact, cracked eyebars, loose or worn pins at pinned connections, and distorted lacing or batten plates on built-up members. Floor beams and stringers in truss bridges often show heavy corrosion under deck joints.

Part H — Bearings and beam ends

Bearings transfer load from the superstructure to the substructure and accommodate rotation and movement. Steel bearings include rocker, roller, sliding plate and pin bearings; elastomeric and pot or disc bearings are also common on steel girders (NCHRP Report 432 covers high-load multi-rotational bearings). Record:

- Bearing type and whether the bearing is in its expected position for the temperature at the time of inspection.
- Excessive tilt of rockers, or rockers near their limits.
- Corrosion that may have frozen sliding or rolling surfaces.
- Cracked or missing anchor bolts, keeper bars or welds.
- Loss of bearing area, either from deteriorated concrete under the masonry plate or from movement toward the seat edge.
- Section loss at the bearing stiffeners and web directly over the bearing.

The beam end is often the worst-corroded part of a steel girder because it sits beneath the joint. Measure web and bearing stiffener section and note any holes or buckling. Bearings are rated as their own MBEI elements.

Part I — Coatings and weathering steel

Paint systems

The coating is the first line of defense. The MBEI steel protective coating element records coating condition by area in condition states. Record chalking, peeling, blistering, rust breakthrough and areas with no coating. Know the system type when possible; many older bridges have lead-based paint, and cleaning, scraping or sampling those surfaces requires the owner's lead-handling procedures to protect the crew and the environment. Localized coating failure under joints and at beam ends is a common reason for spot painting or zone painting, which FHWA's Bridge Preservation Guide recognizes as preservation actions.

Uncoated weathering steel

Weathering steel develops a dense, adherent oxide patina that slows further corrosion when the steel goes through wet and dry cycles. FHWA Technical Advisory T 5140.22 explains that it performs poorly where it stays wet, where it is exposed to salt spray or deicing salts from leaking joints, or where debris holds moisture. What to look for:

- **Good patina:** a fine, tightly adherent, uniform texture, usually dark brown.
- **Problem conditions:** flaking, laminar sheets or large granular flakes, which indicate the patina is not protecting the steel, often near joints and on bottom flanges.
- Debris accumulations, bird nests and vegetation that keep surfaces wet.

A simple field check is to tap or scrape lightly: protective patina stays put; laminar rust comes away in sheets. Where layered rust appears, measure section to check for loss.

Part J — Impact, heat and fire damage

Over-height vehicles strike the bottom flanges of fascia and interior girders over roadways. Record bent or twisted flanges, web distortion, gouges, nicks and tears, and any cracks, particularly at gouges and in the tension flange. Measure the deformation with a straightedge or string line and record the location. A sharp gouge or notch in a tension flange is a crack initiation site and may need an engineer's review even if the bend is minor.

Heat straightening is a common repair for damaged steel members. FHWA's Guide for Heat-Straightening of Damaged Steel Bridge Members describes the controlled process and its limits. At previously heat-straightened locations, look for cracking and residual distortion.

Fires under bridges can distort and weaken steel and damage coatings and bearings. After a fire, owners typically need a special inspection and engineering evaluation; the inspector documents distortion, coating discoloration patterns, and any sagging or misalignment, and does not assume that straight-looking steel retains its original properties.

Welded repairs or attachments made in the field after a hit, or for utilities, can introduce poor fatigue details. Note any welds that were not part of the original structure, and refer to the owner whether they were approved. The AASHTO/AWS D1.5 Bridge Welding Code governs bridge welding.

Part K — Lessons from failures

Much of today's steel inspection practice grew out of specific failures. Knowing the history helps an inspector understand why certain details get so much attention.

- **Silver Bridge, 1967** (Ohio River, Point Pleasant, West Virginia): an eyebar chain suspension bridge collapsed after a crack in one eyebar led to fracture. The collapse prompted Congress to establish national bridge inspection standards, the origin of today's NBIS.
- **Mianus River Bridge, 1983** (I-95, Connecticut): a suspended span fell when a pin-and-hanger assembly failed, with corrosion a key factor. It drove inspection and retrofit of pin-and-hanger details nationwide.
- **Hoan Bridge, 2000** (Milwaukee): girders fractured at a detail where intersecting welds created high constraint, and the span sagged without collapsing. It drew attention to constraint-induced fracture and led to retrofits of similar details.
- **I-35W, 2007** (Minneapolis): the NTSB found that undersized gusset plates, a design error, were the primary cause of the collapse. FHWA then issued gusset plate load rating guidance, and owners looked again at gusset plate condition and capacity.

The common lesson is that a single member or connection can control a nonredundant structure, and that small defects at the right detail can matter. That is why hands-on inspection of NSTMs and careful documentation of connections are required.

Part L — Worked examples

Example 1 — Rust line at a cover plate end

On a rolled-beam bridge built in the 1960s, an inspector sees a thin rust line along the transverse weld toe at the end of a bottom-flange cover plate on G2 in span 2. *Discussion:* Cover plate ends are classic poor fatigue details. Clean the area and

inspect closely with low-angle light and a magnifier; use dye penetrant or another approved method if the owner allows. If a crack is confirmed, record its length and whether it has entered the flange, photograph it, and report it immediately to the engineer. A crack in a tension flange may be a critical finding under the owner's procedures. If no crack is found, record that the detail was cleaned and examined, so the next inspector knows it was checked.

Example 2 — Web gap cracking

Short horizontal cracks are found in the web at the top of several diaphragm connection plates in a negative-moment region of a continuous welded plate girder. The connection plates are welded to the web but not to the top flange. *Discussion:* This is distortion-induced fatigue at a web gap. Record each location, crack length and orientation. These cracks often stabilize, but they can turn and grow into the web under primary stress. Report them for engineering review; FHWA's fatigue repair manual describes common retrofits such as drilling crack tips and attaching the connection plate to the flange.

Example 3 — Beam end section loss

Under a leaking expansion joint, the web of G4 at the pier is heavily corroded above the bearing, with a hole about 1 in by 3 in near the bottom flange and the bearing stiffener reduced in thickness. *Discussion:* Measure the remaining thicknesses with calipers and an ultrasonic gauge, sketch the section, and record the hole size and location. Report to the load rater promptly; beam-end web loss can affect shear and bearing capacity. Recommend repairing the joint as the cause.

Example 4 — Weathering steel with laminar rust

Bottom flanges near the abutments have thick laminar rust sheets, while the rest of the girders show a uniform dark patina. The abutment joints leak. *Discussion:* The patina is not protecting the steel where it stays wet and salty. Remove loose layers in small test areas, measure remaining flange thickness, record the area affected, and recommend joint repair and, where the owner chooses, coating of the girder ends.

Example 5 — Frozen pin-and-hanger

A hanger plate shows heavy pack rust between it and the girder web, and the hanger is visibly out of plumb compared with the previous report's photo at a similar temperature. *Discussion:* A frozen assembly may be carrying bending it was not designed for. Report it immediately per owner procedures, recommend engineering evaluation and, where called for, ultrasonic testing of the pins. Note whether a catcher system is present.

Example 6 — Gouge from a truck strike

A fascia girder over a highway has a sharp gouge about 1/8 in deep in the bottom flange edge and a slight lateral sweep. *Discussion:* Record the gouge depth, length and location, and measure the sweep with a string line. A gouge in a tension flange is a potential crack starter. Recommend evaluation; repairs might include grinding the gouge smooth or heat straightening, as an engineer specifies.

Part M — Nondestructive testing for steel

Visual inspection finds most problems, but some steel defects need NDE to confirm or size. Common methods include:

- **Dye penetrant testing:** a liquid dye drawn into surface-breaking cracks and made visible with a developer. Simple and portable, but it needs a clean surface and only finds cracks open to the surface.

- **Magnetic particle testing:** magnetic particles collect at surface and near-surface cracks in a magnetized area. Useful at welds.
- **Ultrasonic testing:** sound waves detect internal flaws and measure thickness. Used for pins, welds and remaining thickness.
- **Eddy current:** detects surface cracks, sometimes through thin coatings.

NDE should be performed by qualified technicians following the owner's procedures. Record the method, the operator, the area tested and the results, including negative results.

Part N — From findings to ratings and element quantities

The superstructure component rating on a steel bridge reflects the overall condition considering the severity, extent and structural significance of corrosion, cracking, distortion and connection problems. The MBEI element data record the quantities: steel girders in linear feet, trusses by member length, pins and hangers and bearings by each, and the coating by area. Make the two consistent. A single confirmed fatigue crack in a primary tension member can control the superstructure rating, and may justify a low rating even when the rest of the steel is in good condition, because of its consequence. By contrast, widespread surface rust with minimal section loss on redundant members may still support a fair or satisfactory rating, with coating condition recorded separately. Rating guidance and consistency are covered in BR-I05.

When findings change the section properties, tell the load rater. Under 23 CFR 650.313(k), load ratings must be completed as soon as practical but no later than 3 months after an inspection identifies a change that warrants re-rating. The inspector's measurements are what make the re-rating possible.

Part O — When to call the structural engineer

Escalate immediately, following owner procedures, for:

- Any crack in a tension flange, web in a tension zone, NSTM, pin, hanger, eyebar or gusset plate.
- A frozen, misaligned or shifted pin-and-hanger.
- Severe section loss at beam ends, bearing stiffeners, truss members or gusset plates, especially holes through webs.
- Bowed gusset plate edges or distorted connections.
- Major impact damage, or a member that is bent, torn or displaced.
- Bearings that have moved off or near the edge of their seats, or that show loss of support.
- Fire damage to steel members.

Give the engineer the location, member, measurements, photos, traffic impact and what has been done, then document it in writing. If your procedure classifies the condition as a critical finding, follow the notification steps; under 650.313(q), NHS bridges with findings that warrant closure or an NSTM rated 3 or less require FHWA notification within 24 hours.

Part P — Frequently asked questions

Is a rust stain at a weld always a crack?

No, but it must be treated as a possible crack until cleaned and examined. Record what you did to confirm.

Does an NSTM inspection require NDE?

The NBIS defines NSTM inspection as hands-on, using visual techniques that may be supplemented by NDE. Bridge-specific procedures specify when NDE is needed.

Are drilled crack-arrest holes a permanent repair?

They are a common, often effective repair, but cracks can reinitiate. Inspect them every cycle and report any crack beyond the hole.

What counts as redundancy?

Load path, structural (system) and internal redundancy are the three forms recognized in the NSTM definition. Classification is an engineering decision made by the owner, often supported by analysis such as the methods in NCHRP Report 406.

Is this course NBIS refresher training?

No. LoadPath PDH courses are supplemental PDH, separate from FHWA-approved training under 23 CFR 650.309.

Part Q — Summary checklist

- Get within arm's length of NSTMs and fatigue-prone details; record the access you used.
- Know the poor fatigue details: cover plate ends, web gaps, welded attachments, intersecting welds, copes.
- Clean and examine every rust line at a weld before calling it paint failure.
- Measure section loss with calipers and ultrasonic gauges and sketch the remaining section.
- Inspect pins, hangers, gusset plates and bearings for corrosion, distortion and movement.
- Judge weathering steel patina and look for wet, salty, debris-filled areas.
- Escalate cracks in tension members, frozen hangers and severe section loss immediately, and document every escalation.

Part R — Floor systems, cross frames and secondary members

Primary girders and trusses get the attention, but floor systems and secondary members often show the earliest and worst deterioration, and they can cause primary-member problems.

Stringers and floor beams

In truss, arch and girder-floorbeam bridges, the deck sits on stringers that frame into floor beams. These members sit directly under the deck and its joints, so corrosion at stringer ends, floor-beam connections and bearing seats is common. Look for section loss in stringer webs at the connection angles, cracked or corroded connection angles and rivets, and cracks at coped stringer ends. Floor-beam to girder connections can develop distortion-induced cracks because the floor system and the main members deflect differently under load. Record each location by panel point.

Cross frames and diaphragms

Cross frames and diaphragms brace girders and distribute load. Inspect them for loose or missing bolts, bent members from impact or construction, corrosion at the bottom chords, and cracks at their connection plates. Their connections to the girders are where web gap cracking (Part D) starts, so look at both ends of each cross frame.

Lateral bracing

Lateral bracing gusset plates welded to girder webs or flanges are fatigue-sensitive details. Check the welds and the girder base metal near the welds for cracks.

Built-up members

Older riveted members are made of plates and angles joined by rivets, lacing bars or batten plates. Pack rust between components, broken or missing rivets, and bent lacing bars are common. Pack rust that distorts plates should be recorded with the amount of separation. Missing rivets in a connection change its capacity, so record how many and where.

Deck-to-superstructure interface

Steel open-grid decks, orthotropic decks and filled grid decks have their own fatigue and corrosion issues, including cracked welds between grid bars and the supporting members and cracked rib-to-deck welds on orthotropic decks. Where they exist, include them in the plan and use the owner's element definitions.

Part S — More examples for self-check

Example 7 — Missing rivets at a stringer connection

Three of eight rivets connecting a stringer end to a floor beam are missing, and the connection angle has heavy pack rust and visible distortion. *Discussion:* Record the count and position of missing rivets, measure the angle thickness, and note the distortion. Refer it for engineering evaluation; the connection's shear capacity has been reduced. Recommend replacement with high-strength bolts as an engineer specifies, which is a common repair.

Example 8 — Crack at a coped stringer end

A crack starts at the re-entrant corner of a coped stringer flange and runs diagonally into the web for about 2 in. *Discussion:* Cracks at copes are well documented in fatigue literature. Record the crack, photograph it, and refer it to the engineer. A drilled crack-tip hole or a bolted repair may be specified.

Example 9 — Good findings matter too

On a two-girder NSTM bridge, the hands-on inspection of every tension flange and web finds no cracks, minor coating breakdown at two locations and no measurable section loss. *Discussion:* Write that down explicitly: which members were inspected hands-on, from what access, which NDE was used and where, and that no cracks were found. A clean NSTM report is only meaningful if the reader can see that the members were actually examined.

Part T — Quick glossary

- **NSTM:** nonredundant steel tension member (23 CFR 650.305).
- **Hands-on inspection:** inspection within arm's length of the member.
- **Fatigue category:** AASHTO classification of a detail's fatigue resistance, A (best) through E' (worst).
- **Web gap:** the short unstiffened length of web between the end of a connection plate weld and a flange, where distortion-induced cracks start.
- **Pack rust:** corrosion between faying surfaces that forces plates apart.
- **Patina:** the protective oxide on weathering steel.

- **Crack-arrest hole:** a hole drilled at a crack tip to blunt it.
- **Gusset plate:** a plate joining truss members at a panel point.

Part U — Writing the steel findings so others can use them

The same finding can be written in a way that helps or in a way that hides the problem. Compare two notes about the same beam end:

Weak: "G4 has heavy rust at the pier. Monitor."

Strong: "G4, span 2 end at pier 2 (expansion bearing, under leaking finger joint): web 7/16 in original, measured 1/4 in minimum over the bottom 6 in of web for 14 in along the girder; one through-hole 1 in x 3 in, 2 in above the bottom flange; bearing stiffener outstand 1/2 in original, 5/16 in minimum at the bottom. Bearing tilted toward the span, within its range for the temperature at inspection. Photos 23–27. Referred to load rating engineer. Recommend joint repair and beam end repair."

The strong version gives a location anyone can find, measured dimensions, the cause, the photos, the escalation and a recommendation. It can be used directly in a load rating, a repair design or a comparison next cycle.

Tips

- Use the owner's member naming convention consistently in text, sketches and photos.
- State the original dimension and its source (plans or measured on an unaffected area).
- Say what was cleaned and examined, and what NDE was used.
- Separate observation from interpretation: "rust line along weld toe, cleaned; dye penetrant indicated a 1-1/4 in crack" rather than "probably cracked."
- Compare explicitly with the previous report, and say whether each condition is new, unchanged or worse.

Part V — A reviewer's checklist for steel inspection reports

Engineers who review or rely on reports can use these questions. They are also a useful self-check for team leaders before a report is submitted for quality control review, because a reviewer will ask them anyway and it is faster to answer them while still in the field:

1. Were all NSTMs inspected hands-on, and does the report say how they were accessed?
2. Are fatigue-prone details listed and each one addressed, even if no crack was found?
3. Is section loss reported with measured remaining thickness, extent and location?
4. Are pins, hangers, gusset plates and bearings specifically addressed?
5. Do the superstructure rating and the element quantities tell the same story?
6. Were cracks and other urgent findings escalated, and is the escalation documented?
7. Are causes, such as leaking joints, identified and recommendations prioritized?
8. Have findings that change section properties been sent to the load rater, with the 3-month load rating clock in mind?

A report that answers yes to all of these is one an engineer can sign off on, rate from, and build a repair program around.

Closing thought

Steel bridges usually give warning before they fail: rust lines at welds, pack rust that bends plates, hangers that lean, bearings that tilt, gusset edges that bow. The value of the inspection lies in getting close enough to see those warnings, measuring them

carefully, and making sure the right engineer hears about them in time. Most of the steel failures that shaped today's rules came down to a small detail that either was not seen or was not acted on. Carry that lesson onto every steel bridge you inspect or review, and treat every unexplained rust line, distorted plate or leaning hanger as a question that needs a documented answer.

Key takeaways

- Corrosion concentrates under joints and at bearings.
- Record remaining thickness and extent for raters.
- Weathering steel needs wet-dry cycling to protect itself.
- Fatigue details and NSTMs need close, hands-on attention.

References

1. FHWA, Bridge Inspector's Reference Manual (BIRM), FHWA-NHI-12-049, 2012 (as revised)
2. AASHTO, Manual for Bridge Element Inspection, 2nd Edition, 2019
3. FHWA Technical Advisory T 5140.22, Uncoated Weathering Steel in Structures, 1989
4. FHWA, Specifications for the National Bridge Inventory (SNBI), FHWA-HIF-22-017, March 2022
5. 23 CFR Part 650, Subpart C — National Bridge Inspection Standards (final rule published May 6, 2022)
6. AASHTO, LRFD Bridge Design Specifications, 9th Edition, 2020
7. FHWA, Manual for Repair and Retrofit of Fatigue Cracks in Steel Bridges, FHWA-IF-13-020, 2013
8. FHWA, Guide for Heat-Straightening of Damaged Steel Bridge Members, FHWA-IF-08-999, 2008
9. FHWA, Load Rating Guidance and Examples for Bolted and Riveted Gusset Plates in Truss Bridges, FHWA-IF-09-014, 2009
10. NCHRP Report 406, Redundancy in Highway Bridge Superstructures, 1998
11. NCHRP Report 432, High-Load Multi-Rotational Bridge Bearings, 1999
12. AASHTO/AWS D1.5M/D1.5, Bridge Welding Code (current edition)
13. FHWA, Bridge Preservation Guide: Maintaining a Resilient Infrastructure to Preserve Mobility, FHWA-HIF-18-022, 2018
14. FHWA, Steel Bridge Design Handbook, FHWA-HIF-16-002 (multi-volume), 2015

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