Inspecting Concrete Decks and Superstructures

Concrete decks and superstructures make up most of the inventory. This course covers what concrete defects look like, how to find them, and how to quantify and rate them so engineers can act.

Learning objectives

- Recognize cracking, delamination, spalling and efflorescence
- Use sounding and visual methods effectively
- Rate and quantify concrete defects
- Flag conditions that need engineering follow-up

Concrete defect vocabulary

- **Cracking** — flexural, shear, longitudinal, transverse, map (pattern) and plastic shrinkage. Record width, length, orientation and whether rust staining or efflorescence is present.
- **Delamination** — a subsurface separation, usually at the reinforcement level from corrosion; found by sounding.
- **Spalling** — a depression where concrete has separated and fallen away, often exposing reinforcement.
- **Efflorescence** — white deposits from water moving through cracks; rust-stained efflorescence suggests corroding steel.
- **Scaling** — surface mortar loss from freeze-thaw and deicers.
- **Honeycombing** — construction voids.

Finding hidden deterioration

Hammer sounding and chain dragging detect delaminations by a hollow sound. Mark areas with paint and measure. For larger decks, NDE methods such as GPR, infrared thermography and impact-echo help map deterioration (see ACI 228.2R and BR-N01). Look at the deck underside: wet areas, efflorescence and rust stains often mirror topside deterioration and reveal problems under overlays.

Concrete superstructures

Reinforced concrete T-beams and slabs: look for flexural cracks near midspan, diagonal shear cracks near supports, and spalls at drip lines and joints. **Prestressed beams:** any longitudinal crack along strands with rust staining is significant; check beam ends under leaking joints, impact damage on fascia beams and bottom flanges over traffic. **Adjacent box beams:** watch for reflective longitudinal cracks indicating shear key failure and differential deflection.

Quantifying and rating

Under the MBEI, record deck defects in square feet by condition state; girders in linear feet. Map delaminations, spalls and patches. Note percentages of deck area deteriorated — agency preservation and rehabilitation decisions often hinge on these numbers (see ACI 345.1R for maintenance strategies by condition).

Component ratings should reflect the extent and structural significance: widespread delamination over 25–30% of a deck area typically pushes toward a 4 or 5; a single spall with exposed bars may still be a 6.

When to call the structural engineer

- Shear cracks wider than hairline near supports.
- Exposed and corroded prestressing strands or broken wires.
- Spalls that can fall onto traffic below.
- Punching or full-depth holes in decks.
- Significant deflection or sagging.

These may be critical findings or require rating review; follow agency procedures.

Part A — Learning objectives and how to use this course

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

- Describe the main mechanisms that deteriorate concrete bridge decks and superstructures: corrosion of reinforcement, freeze-thaw damage, alkali-silica reaction, sulfate attack, and structural distress from load.
- Recognize and describe each common concrete defect in terms a reviewer and a load rater can use: cracking, delamination, spalling, efflorescence, scaling, honeycombing, abrasion and exposed or corroded reinforcement.
- Plan a deck and superstructure inspection, including access, tools, sequence and how to record quantities.
- Recognize the defects that matter most on reinforced concrete slabs and T-beams, prestressed I-girders, adjacent box beams and post-tensioned members.
- Quantify deterioration by element and condition state under the AASHTO Manual for Bridge Element Inspection, and translate those quantities into a defensible component condition rating.
- Decide when a finding needs an engineer's immediate attention, a load rating review or a critical finding under the owner's procedures.

This course is written for engineers who review, rate, or use inspection reports as well as for those who perform inspections. Read the worked examples, decide what you would record before reading the discussion, and compare your reasoning. The 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), ACI 345.1R on maintenance of concrete bridge members, ACI 228.2R on nondestructive testing, and NCHRP Report 280 on evaluating and repairing damaged prestressed members. Always defer to your owner agency's adopted manuals, because many states publish their own element definitions, condition-state guidance and photo standards.

Part B — Why concrete deteriorates: the mechanisms behind the defects

An inspector who understands *why* a defect formed writes a better report and makes better predictions about where to look next. Most concrete deterioration on bridges traces back to water. Water carries chlorides, feeds freeze-thaw damage, sustains chemical reactions and provides the electrolyte that corrosion needs. Following the water is the single most useful habit in concrete inspection.

Chloride-induced corrosion of reinforcement

Concrete normally protects embedded steel because its high alkalinity forms a passive film on the bar surface. Chlorides from deicing salts or a marine environment migrate through the cover concrete, and once enough accumulate at the bar the passive film breaks down and corrosion begins. Carbonation, the slow reaction of the paste with carbon dioxide, can also lower alkalinity at the bar, though on most highway decks chlorides are the dominant cause. Corrosion products occupy a larger volume than the original steel. That expansion creates tensile stress in the surrounding concrete, which leads first to cracking along the bar, then to a horizontal fracture plane at the level of the reinforcement (a delamination), and finally to spalling when the cover breaks free. This sequence is why delaminations are so often found before any spall is visible, and why sounding is essential.

Freeze-thaw damage and scaling

When saturated concrete freezes, water expanding in the pores can damage the paste if the concrete lacks an adequate entrained-air void system. The result at the surface is scaling: flaking or peeling of the surface mortar, sometimes progressing until coarse aggregate is exposed. Deicing chemicals can make scaling worse. Some aggregates are themselves vulnerable to freezing and produce a pattern of fine cracks parallel to joints and edges, often called D-cracking, which usually starts where moisture collects.

Alkali-silica reaction (ASR)

Certain reactive silica in aggregates reacts with alkalis in the cement paste to form a gel that swells as it absorbs water. The typical sign is map or pattern cracking, sometimes with a gel exudation or staining along the cracks. In members with strong restraint or prestress, the cracks may align with the main reinforcement or the prestressing direction. ASR is diagnosed by laboratory petrography, not by eye; an inspector should describe what is seen and recommend testing rather than declaring ASR in the field.

Sulfate attack and other chemical exposure

Sulfates in soil or water can attack concrete in footings, piles and culverts. The paste softens and expands, producing cracking and loss of section. This is more common in substructures than decks and is addressed further in the substructure course (BR-I08).

Structural distress

Not every crack is a durability problem. Flexural cracks, shear cracks, cracks from restrained shrinkage and thermal movement, and cracks from overload or impact each have characteristic locations and orientations. Distinguishing a structural crack from a durability crack is one of the most important judgments in concrete inspection, because structural cracks may affect load capacity and may need an engineer's review. Part E covers crack patterns in detail.

Why this matters to the report

A note that says "spall, 2 sq ft" is useful. A note that says "spall, 2 sq ft, at the drain outlet on the fascia, with exposed bottom bar showing surface corrosion; surrounding area sounds hollow for about 6 sq ft; cause appears to be drainage onto the fascia" is far more useful. It tells the owner the extent, the condition of the steel, the likely growth, and the fix (deal with the drainage). That is the level of description this course aims for.

Part C — Concrete defect vocabulary in depth

The BIRM and the MBEI define the vocabulary used in inspection. Using the same words the same way is what makes reports comparable from cycle to cycle and inspector to inspector. The list below expands on the short definitions in Part A of the original course outline.

Cracking

Record the type, location, orientation, length, width, spacing where there is a pattern, and any rust staining, efflorescence or moisture. Measure widths with a crack comparator card or a crack-width gauge rather than estimating by eye, and mark the measured location so the next inspector can compare. Common types include:

- **Flexural cracks**: perpendicular to the span in regions of high moment, such as the bottom of a beam near midspan or the top of a continuous member over a support.
- **Shear cracks**: diagonal, typically in the web near supports, inclined toward midspan as they rise.
- **Longitudinal cracks**: parallel to the span. On a deck they may follow bars or girder lines; on a prestressed beam they may follow strands, which is especially significant.
- **Transverse cracks**: across the deck, often regularly spaced and frequently related to restrained shrinkage.
- **Map or pattern cracking**: an interconnected network, often related to shrinkage, ASR or freeze-thaw.
- **Plastic shrinkage cracks**: short, shallow cracks that form while the concrete is still plastic, typically of less structural concern.

Delamination

A subsurface separation roughly parallel to the surface, usually at the level of the top mat of reinforcement in decks and caused by corrosion. Delaminations are invisible until they spall, so they are found by sounding (hammer or chain drag) or by nondestructive evaluation. Mark the boundaries with paint and measure the area.

Spalling

A depression created where concrete has separated from the member and fallen or been removed. Record dimensions, depth and whether reinforcement is exposed. Note the condition of exposed steel: surface corrosion only, or measurable section loss. On members over traffic or pedestrians, spalls and loose concrete are also a safety hazard.

Efflorescence

A white deposit left as water moves through the concrete and evaporates at the surface, carrying dissolved salts. Efflorescence shows that water is passing through a crack or joint. When it is stained rust-brown, the water is likely carrying corrosion products, which points to corroding reinforcement.

Scaling

Loss of surface mortar. Record extent and depth. Light scaling exposes only the surface; heavier scaling exposes coarse aggregate. Scaling mainly affects ride quality and durability, but on decks it also reduces cover over the top reinforcement.

Honeycombing and voids

Areas where mortar did not fill around coarse aggregate during placement, leaving voids. Usually a construction defect. Note it because it reduces cover and allows water ingress.

Abrasion and wear

Loss of surface from traffic, studded tires, plowing, or water-borne debris on substructures. On decks, wear can reduce cover; on piers in streams, abrasion can be heavy at the waterline.

Exposed reinforcement and section loss

Report the bar location and approximate size if known from plans, and estimate section loss conservatively. On prestressed members, report exposed strands separately and record whether any wires appear broken. Never pry at strands to "check" them.

Patches

Prior repairs are part of the condition record. The MBEI treats patched areas through its defect definitions, and many owners track them separately. Sound around patches; a patch that sounds hollow, or concrete that has delaminated next to a patch, suggests corrosion continuing in the surrounding contaminated concrete.

Part D — Planning and performing a concrete deck inspection

Before the field visit

Review the previous reports, photos and element quantities, the plans if available, and any repair or overlay history. Note the deck type (cast-in-place, precast panels, adjacent beams acting as the deck), the wearing surface (bare concrete, asphalt overlay, latex- or silica-fume-modified concrete overlay, polymer overlay), whether the bars are epoxy-coated, and the joint and drainage layout. An asphalt overlay hides the top of the deck, so the underside and any cores or NDE data become more important. Plan traffic control and access with the owner; the inspection is only as good as what the team can safely reach.

Sequence on the topside

1. Walk the deck to get the overall picture: wearing-surface condition, cracking pattern, patches, potholes, ponding, joint condition and drainage.
2. Sound the deck, either with a chain drag across the full width or with a hammer on a grid, marking hollow areas with paint.
3. Measure the marked areas and record them by span, and by lane or bay where the owner's practice calls for it.
4. Photograph representative and worst-case areas with a scale reference and a location label.
5. Inspect curbs, barriers and the deck edge, where water and salt collect.
6. Inspect the joints and drains, because their failure usually drives the worst deterioration on the deck underside and the beam ends.

Sequence on the underside

The underside often tells the truth about a deck covered by an overlay. Look for efflorescence, rust staining, wet areas, cracking, spalls and exposed bars. Map them by bay. Pay particular attention to overhangs and fascia areas below drains, the bays next to joints, and areas under the wheel paths. Underside spalls over traffic, rail, a trail or a parking area should be noted as a potential falling-concrete hazard and reported per the owner's procedure, often with a recommendation to remove loose material immediately.

Tools

A typical kit includes a sounding hammer and chain, crack comparator card, tape and measuring wheel, marking paint, a flashlight, a camera, a moisture meter if the owner uses one, and the field forms or tablet. Access may require a snooper truck, lift or ladder. Some owners supplement the visual and sounding inspection with NDE (Part H).

Safety reminders

Concrete inspection involves traffic, heights, confined spaces in box girders, and falling material. Follow the owner's safety plan and traffic-control requirements, wear the required PPE, and never put an inspection quantity ahead of crew safety. When a deck cannot be safely sounded, say so in the report rather than estimating as if it had been.

Part E — Reading crack patterns: structural or durability?

A crack pattern is evidence. Before deciding what a crack means, record where it is, which direction it runs, how wide it is, whether it is active (growing, stained, wet), and what the member is doing structurally at that location.

Pattern	Typical location	Likely cause	Significance
Vertical cracks at bottom of beam near midspan	Positive-moment region	Flexure	Fine, evenly spaced cracks are expected in reinforced concrete; widening or staining warrants attention
Diagonal cracks in web	Near supports	Shear	Structurally important; report width and length and refer to a structural engineer if more than hairline or growing
Cracks at top of continuous deck over piers	Negative-moment region	Flexure and restraint	Common; a path for water and chlorides into the deck
Regularly spaced transverse deck cracks	Full length of deck	Restrained shrinkage and thermal effects	Usually not structural, but they admit water and chlorides
Longitudinal crack over a bar or strand, with rust stain	Deck, beam bottom flange	Corrosion of the bar or strand	Significant; on prestressed beams potentially serious
Map cracking with gel or staining	Any exposed surface, often wet areas	Possible ASR or freeze-thaw	Recommend sampling and testing; do not diagnose in the field
Cracks radiating from bearing areas	Beam ends, caps	Bearing restraint, high local stress, or corrosion at a leaking joint	Check the bearing and the joint above; note any loss of bearing area

Two general rules help. First, cracks perpendicular to the main tension reinforcement in tension zones are expected in reinforced concrete and are normally not a concern while they remain fine and dry. Second, cracks that are diagonal near supports, that follow the reinforcement, that show staining, or that are getting wider are the ones that need attention. Prestressed members are designed to limit cracking under service loads, so a crack in a prestressed member deserves more scrutiny than a similar crack in a conventionally reinforced member (Part F).

Measuring and tracking

Measure width at a marked location and record the method. On the next cycle, measure at the same spot with the same method. Owners may use crack monitors or gauges on cracks that are being watched. Without repeatable measurements, "the crack looks bigger" is not evidence. Photograph with a scale and a label in the frame.

Part F — Superstructure types and what to look for on each

Reinforced concrete slabs

Slab bridges carry load directly in the slab. Look at the underside for flexural cracking, efflorescence, spalls and exposed bars, especially under joints and along the edges where drainage runs off. Longitudinal cracking may reflect differential behavior between parts of the slab. Because the slab is both deck and superstructure, the same deterioration may influence both component ratings; rate each according to its role as defined in the SNBI and the owner's guidance.

Reinforced concrete T-beams

T-beam stems carry the flexure and shear; the flange is the deck. Typical problems are diagonal shear cracks near the supports, flexural cracks near midspan, spalls at stem bottoms where water drips, and deterioration at beam ends under leaking joints. Older T-beams may have limited shear reinforcement compared to current practice, so an engineer will usually want accurate shear crack data. Record the stem, the location from the bearing, the length and width of each significant diagonal crack.

Prestressed concrete I-girders and bulb-tees

Prestressed girders are designed to be essentially uncracked under service loads. Key concerns are:

- **Longitudinal cracks along the bottom flange** following strands, especially with rust staining: these often indicate strand corrosion.
- **Spalls exposing strands**: record the number of exposed strands, their condition, and any broken wires.
- **Impact damage** from over-height vehicles on fascia and first-interior girders over a roadway: record gouges, spalls, cracking, exposed or severed strands, and any lateral displacement.
- **End-region deterioration** under leaking joints, where chloride-laden water attacks the girder ends and bearing areas.
- **Flexural or web cracks** in any prestressed girder, which may indicate overload, loss of prestress or other distress and should be referred to an engineer.

NCHRP Report 280 and the earlier NCHRP Report 226 give guidance for evaluating and repairing damaged prestressed members, including how the number and location of damaged strands affect repair options. The inspector's job is to provide the data those methods need: which strands, where along the span, how much section is gone, and whether concrete around them is sound.

Adjacent box beams and voided slabs

Adjacent box beams are placed side by side and connected by grouted shear keys and, in many designs, transverse ties. Reflective longitudinal cracking in the wearing surface over the joints between beams suggests shear-key failure. When the keys fail, beams can act independently, water and chlorides reach the beam sides and bottoms, and differential deflection may be visible as a step in the deck surface under load. Because the strands are hidden inside the box, deterioration is often advanced before it shows. Look for wet joints, efflorescence and rust staining between beams, longitudinal cracks along the

bottom flanges, and spalls exposing strands. Moisture trapped in the voids can also be a concern; follow the owner's guidance on drain holes.

Cast-in-place and segmental box girders

Box girders require interior inspection. Plan for confined-space entry, lighting and ventilation per the owner's safety program. Inside, look for web and slab cracking, efflorescence and leakage, and the condition of tendons, anchorages and deviators on post-tensioned structures.

Post-tensioned members

Grouted post-tensioning tendons are protected by the duct and grout. Voids in the grout, water intrusion, and deficient anchorage protection can lead to strand corrosion that is not visible from outside. Signs include rust staining or efflorescence along a duct path, cracks along tendons, and deterioration at anchorage pockets. FHWA's Post-Tensioning Tendon Installation and Grouting Manual describes good practice and the problems that poor grouting can cause. When signs of tendon distress appear, an engineer typically decides whether specialized investigation is warranted.

Part G — Joints, drainage and bearings: the sources of the worst damage

Many of the worst concrete problems on a bridge are not caused by the concrete. They are caused by water and salt delivered by a failed joint or a clogged or short drain. NCHRP Synthesis 319 on bridge deck joint performance documents how commonly joints leak and how leakage drives deterioration of beam ends, bearings and substructure tops.

- Inspect each joint for seal condition, debris, leakage and damage to the armor or headers.
- Trace drainage paths: scuppers, downspouts and outlets. A drain that discharges onto a beam or pier is a deterioration engine.
- At beam ends and bearings, look for corrosion staining, spalls, cracking and loss of bearing seat area. Record the bearing type and condition, because bearings that cannot move can crack concrete.

When you report the deterioration, also report the source. Recommending that a joint be resealed or a drain extended is often the most cost-effective action in the whole report, and FHWA's Bridge Preservation Guide treats joint and drainage maintenance as core preservation activities.

Part H — Nondestructive evaluation for decks

Visual inspection and sounding remain the foundation, but nondestructive evaluation (NDE) can map deterioration across a whole deck, see under overlays, and support repair-versus-replace decisions. ACI 228.2R surveys the methods. Common tools include:

- **Ground-penetrating radar (GPR)**: measures reflections from the reinforcement and interfaces. Attenuation of the signal is associated with conditions favorable to corrosion. ASTM D6087 covers evaluating asphalt-covered decks with GPR.
- **Infrared thermography**: detects delaminations as temperature differences on the surface under suitable sun and weather conditions.
- **Impact-echo and related acoustic methods**: detect delaminations and voids by the response to a mechanical impact.
- **Half-cell potential**: ASTM C876 describes measuring corrosion potentials of uncoated reinforcement to indicate the probability of active corrosion. It is not appropriate for epoxy-coated bars without special consideration.

- **Cover meters**: locate bars and estimate cover.
- **Cores and chloride testing**: destructive but definitive for concrete quality and chloride content at bar depth.

Each method has limits. GPR interpretation depends on calibration and experience; thermography depends on weather; half-cell readings require electrical continuity and suitable moisture. Results are most reliable when correlated with sounding and some cores. When NDE is used, record the method, the vendor or operator, the conditions, and how results were verified, and keep the NDE data with the bridge file. NDE is covered in more depth in BR-N01.

Part I — Quantifying by element and condition state

The MBEI defines national bridge elements (for example, reinforced concrete deck, prestressed concrete girder, reinforced concrete slab) and defects for each, with four condition states: 1 Good, 2 Fair, 3 Poor, and 4 Severe. Decks and slabs are quantified in square feet, girders and beams in linear feet, and some elements as each. The inspector distributes the total element quantity among the four condition states according to the defects found, using the MBEI defect descriptions and the owner's supplemental guidance.

A practical process

1. Start with the total element quantity from the inventory (for example, the deck area).
2. Assign the measured areas of spalls, delaminations and patches to condition states using the MBEI defect tables and owner guidance. Spalls with exposed corroded bars are generally worse than tight cracking.
3. Assign cracking by the extent affected and its characteristics (width, spacing, staining) as the owner's definitions direct.
4. Put the remainder in the appropriate state, usually state 1 if no defects are present.
5. Check that the states sum to the total.

Wearing surfaces and protective systems

The MBEI separates the wearing surface from the deck element. Record overlay condition under the wearing-surface element, and do not double-count. If the overlay hides the deck top, the deck quantities depend on the underside, sounding through the overlay where practical, and NDE.

From elements to the component rating

Element data and the 0–9 component condition rating describe the same bridge in different ways, so they should tell a consistent story. The component rating is a judgment of overall condition considering severity, extent and structural significance; the element data give the quantities behind it. A deck with a small percentage of its area in states 3 and 4 and otherwise sound concrete might reasonably be rated in the fair-to-satisfactory range, while a deck with widespread delamination and spalling across many bays would be rated lower. Specific percentage thresholds vary by owner; where your agency publishes guidance relating quantities to ratings, use it. The BR-I05 course covers the 0–9 scale and rating consistency in detail.

Part J — Worked examples

Example 1 — Overlay hiding the deck

A three-span deck has an asphalt overlay with several patches and longitudinal cracks over the girder lines. The underside shows efflorescence with rust staining in many bays and two small spalls with exposed bottom bars. *Discussion:* The overlay

hides the top of the deck, but the underside indicates water and chloride penetration through the full depth. Record underside quantities by bay, sound the overlay where possible, and recommend NDE or cores to estimate the extent of top-mat deterioration before any overlay replacement is designed. Do not rate the deck as if the top were sound simply because it cannot be seen; note the limitation.

Example 2 — Fascia prestressed girder struck by a truck

The bottom flange of a fascia girder over a highway has a spall about 3 ft long with two strands exposed; one strand appears to have several broken wires. *Discussion:* Record the location along the span, the strands affected, the extent of spalled and delaminated concrete, and any cracking or lateral displacement. Remove loose concrete over traffic if the owner's procedure allows, or request it. Notify the structural engineer promptly: damaged strands reduce capacity, and the owner's critical-findings procedure may apply depending on the evaluation. NCHRP Report 280 provides methods to evaluate and repair such damage.

Example 3 — Adjacent box beams with reflective cracking

A 40-year-old adjacent box beam bridge shows longitudinal cracks in the wearing surface over most beam joints, with efflorescence and rust staining between beams on the underside. One exterior beam has a longitudinal crack along its bottom flange with staining. *Discussion:* The pattern indicates shear-key leakage and probable strand corrosion in at least one beam. Record each joint and beam, recommend that an engineer evaluate the beam with the longitudinal crack, and consider whether the bridge is performing as a system. This is a situation where deterioration is often worse than it looks.

Example 4 — Shear cracks in a T-beam

Diagonal cracks appear near the bearings in several T-beam stems, up to about 0.02 in wide, with no staining. The previous report recorded hairline cracks at the same locations. *Discussion:* Report the cracks with locations, lengths and widths, compare with the previous measurements, and refer them to an engineer, because shear cracks in older T-beams can matter for load rating. Recommend monitoring at marked locations.

Part K — When to call the structural engineer, and what to tell them

Escalate immediately, following the owner's procedures, when you find conditions such as:

- Diagonal shear cracks that are wider than hairline, growing, or accompanied by displacement.
- Exposed, corroded, or broken prestressing strands, or longitudinal cracking with staining along strands.
- Loose concrete that can fall onto traffic, a railroad, a trail or people below.
- Punch-throughs, full-depth holes or areas of a deck that may not carry wheel loads.
- Visible sag, unusual deflection, or loss of bearing.
- Signs of tendon distress on post-tensioned structures.

Under 23 CFR 650.313(q), owners must have critical-finding procedures that, at a minimum, capture conditions such as those warranting closure or a component rated 2 or less. Many owners define additional triggers. When you call, give the engineer the essentials: the bridge and location, the member, what you see, the measurements, photos, whether traffic is affected, and what you have already done (for example, cleared loose concrete or requested a lane closure). Then write it down in the report and in whatever notification record the owner uses. A finding that exists only in a phone call is not documented.

Part L — Summary and documentation checklist

- Follow the water: joints, drains and overhangs drive most deterioration.
- Sound everything you can; delaminations come before spalls.
- Describe each defect with location, size, orientation, width and the condition of any exposed steel.
- Treat cracks in prestressed members, longitudinal cracks along strands, and diagonal shear cracks with extra care.
- Quantify by MBEI element and condition state, keep the wearing surface separate, and check that quantities sum.
- Make the component rating and the element data tell the same story.
- Use NDE where it adds value and record how it was done and verified.
- Escalate hazards promptly and document every escalation.

A good concrete inspection report lets an engineer who has never seen the bridge understand what is wrong, how much of it there is, why it is happening and what should happen next.

Part M — From findings to action: preservation and repair options

Inspectors are not usually the designers of repairs, but recommendations are part of a good report, and engineers who read reports need to know what the findings imply. ACI 345.1R on maintenance of concrete bridge members and ACI 546R on concrete repair describe the range of actions. FHWA's Bridge Preservation Guide frames them as preventive maintenance, condition-based maintenance, rehabilitation and replacement.

Preventive actions

- **Deck washing and drain cleaning** to remove salt and debris.
- **Crack sealing** to limit water and chloride entry through individual cracks.
- **Penetrating sealers** to reduce water and chloride absorption on sound concrete.
- **Joint resealing or joint elimination** to stop leakage onto beam ends and substructures.
- **Thin polymer overlays** on decks in relatively good condition.

Condition-based repairs

- **Partial-depth and full-depth patching** of delaminated and spalled areas, removing concrete beyond the delaminated boundary and around corroded bars as the repair specification requires.
- **Rigid overlays** such as latex-modified or silica-fume concrete after removal of deteriorated concrete.
- **Strand repair or splicing** on damaged prestressed girders, and in some cases externally bonded FRP strengthening (ACI 440.2R), as evaluated by an engineer.

Rehabilitation and replacement

When deterioration is widespread, patching becomes a cycle of repeated work. Deck replacement or superstructure replacement may then be more economical. Those decisions are informed by the quantities the inspector records, the trend over several cycles, and NDE or chloride data. That is why consistent measurement from cycle to cycle matters: the owner's decision may rest on whether deteriorated area is stable or growing.

Wording recommendations

Write recommendations that can be acted on and prioritized: what, where, and how urgent. "Seal joint at pier 2 and extend the drain at the east fascia of span 3 to discharge clear of the girder" is better than "address drainage." Follow the owner's priority

coding where one exists, and separate safety-related recommendations from routine maintenance so they are not lost.

Part N — Photographs and field notes that hold up

Photos and notes are how the next inspector, the load rater and the repair designer see the bridge. A few habits make them far more useful:

- Take an overall photo that locates the defect on the bridge, then a close-up with a scale (tape, crack card or a marked rule) in the frame.
- Label each photo with the span, member and location using the owner's naming convention, and reference the photo number in the narrative.
- Repeat key photos from the same viewpoint each cycle so change is visible.
- Record what you could not see or access, and why: overlay, debris, traffic, water or lack of equipment. A limitation stated clearly is better than an assumption hidden in a rating.
- Keep sketches of delamination maps and crack maps with dimensions. A hand sketch with measurements is more valuable than a photo without them.

The BR-I10 course covers report quality control in more detail.

Part O — Frequently asked questions

Is every crack in a deck a problem?

No. Fine shrinkage and flexural cracks are normal in reinforced concrete. They become a concern when they allow water and chlorides to reach the steel, when they show staining, when they are wide or growing, or when their pattern suggests structural distress. Record them, but describe their significance honestly.

Can I rate a deck I could not sound?

You must still assign a rating, but base it on what you could observe and state the limitation in the report. Recommend sounding or NDE at the next opportunity. Do not imply a level of investigation that did not happen.

Why does the underside matter so much when the deck has an overlay?

Because the overlay hides the top, and deterioration that reaches the underside often indicates the deck is contaminated through much of its depth. Efflorescence with rust staining, wet areas and underside spalls are strong evidence.

How do I handle a prestressed beam with one exposed strand?

Record its location, the length exposed, the condition of the strand (surface corrosion, pitting, broken wires) and the surrounding concrete. Report it to the engineer per the owner's procedures. Even a single damaged strand can matter in a member with few strands, and only an evaluation can tell.

What about epoxy-coated reinforcement?

Epoxy coating slows corrosion but does not make a deck immune, particularly where the coating was damaged. Some methods, such as half-cell potential, are not straightforward on epoxy-coated bars. Note the bar type from plans when known so the reader can interpret findings.

Does this course meet NBIS refresher requirements?

No. LoadPath PDH courses are supplemental PDH for engineers. FHWA-approved comprehensive and refresher training under 23 CFR 650.309 is separate.

Part P — More worked examples for self-check

Example 5 — Scaling on a bare deck

A bare concrete deck in a northern climate has light-to-moderate scaling across the wheel paths, with some coarse aggregate exposed, and no delaminations found by chain drag. The underside is dry and clean. *Discussion:* The scaling is a surface durability problem that reduces cover and ride quality, but the sounding and the clean underside suggest the reinforcement is not yet affected. Record the extent and depth, place the affected area in the appropriate MBEI condition state, and recommend a sealer or overlay strategy per the owner's preservation program. The component rating should reflect the surface deterioration without overstating its structural significance.

Example 6 — Map cracking with gel deposits

A pier cap and the adjacent girder ends show map cracking with a whitish, glassy deposit in some cracks, mostly in areas wetted by a leaking joint. *Discussion:* The pattern is consistent with ASR or another moisture-related mechanism, but the cause cannot be confirmed visually. Describe the cracking and deposits, map the extent, recommend cores for petrographic examination, and recommend fixing the joint, because moisture fuels most of these reactions.

Example 7 — Deck underside spall over a sidewalk

An overhang spall about 1 sq ft with a loose, cracked piece still attached is found above a busy sidewalk. *Discussion:* This is a safety issue first. Follow the owner's procedure: remove the loose concrete if the crew is authorized and equipped, or request immediate removal and protection, and notify the responsible engineer. Then record the spall, the surrounding hollow area and the bar condition as for any other defect. The report should show both the hazard response and the condition data.

Example 8 — Cracks that did not change

Transverse deck cracks recorded at 0.01 in five years ago measure the same today at the same marked locations, with no staining. *Discussion:* Stability is a finding too. Say so explicitly. A sentence such as "transverse cracks at marked locations unchanged from previous cycle" is valuable evidence for the owner and justifies a stable rating.

Reflection

In each example, notice that the useful output is not only a number. It is a description of what is there, how much, what caused it, whether it is changing, and what should happen next. That is the inspection product engineers rely on.

Part Q — Quick glossary

- **Cover**: the concrete between the reinforcement and the surface; it protects the steel.
- **Passive film**: the protective oxide layer on steel in alkaline concrete; chlorides and carbonation break it down.
- **Chain drag**: dragging a chain across a deck to find delaminations by sound.
- **Condition state**: one of four MBEI states (Good, Fair, Poor, Severe) used to distribute element quantities.
- **Wearing surface**: the riding surface or overlay, recorded as its own element.

- **Shear key**: the grouted joint between adjacent box beams that makes them share load.
- **Petrography**: laboratory microscopic examination of concrete, used to diagnose ASR, freeze-thaw damage and other mechanisms.
- **Half-cell potential**: an electrical measurement indicating the probability of active corrosion of uncoated reinforcement (ASTM C876).
- **Efflorescence**: salt deposits left by water passing through concrete.
- **Critical finding**: a structural or safety-related deficiency requiring immediate action to ensure public safety (23 CFR 650.305).

Keep this list handy when reading or writing reports; consistent terms are what make one inspection comparable with the next.

Key takeaways

- Know the vocabulary: cracks, delaminations, spalls, efflorescence, scaling.
- Sound decks; read the underside for hidden problems.
- Prestressed strand exposure and longitudinal cracking are serious.
- Quantify by area and condition state; escalate structural cracking and falling concrete.

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. ACI 345.1R-16, Guide for Maintenance of Concrete Bridge Members
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. NCHRP Report 280, Guidelines for Evaluation and Repair of Prestressed Concrete Bridge Members, 1985
7. NCHRP Report 226, Damage Evaluation and Repair Methods for Prestressed Concrete Bridge Members, 1980
8. FHWA, Post-Tensioning Tendon Installation and Grouting Manual, FHWA-NHI-13-026, 2013
9. NCHRP Synthesis 319, Bridge Deck Joint Performance, 2003
10. FHWA, Bridge Preservation Guide: Maintaining a Resilient Infrastructure to Preserve Mobility, FHWA-HIF-18-022, 2018
11. ACI 546R-14, Guide to Concrete Repair
12. ACI 440.2R-17, Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures
13. ACI 228.2R-13, Report on Nondestructive Test Methods for Evaluation of Concrete in Structures
14. ASTM C876, Standard Test Method for Corrosion Potentials of Uncoated Reinforcing Steel in Concrete
15. ASTM D6087, Standard Test Method for Evaluating Asphalt-Covered Concrete Bridge Decks Using Ground Penetrating Radar

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