

# Substructure Inspection: Abutments, Piers and Bents

Substructures carry everything. This course covers abutments, piers and bents — how they deteriorate, how to spot movement, and how substructure findings connect to scour and load rating.

## Learning objectives

- Describe common substructure types
- Recognize settlement, rotation and undermining
- Inspect pile bents and pier caps
- Connect findings to scour and load rating

## Substructure types

Abutments (full-height, stub, spill-through, integral), piers (solid wall, hammerhead, multi-column), and bents (pile bents, framed bents). Foundations may be spread footings, driven piles or drilled shafts. The foundation type matters greatly for scour vulnerability — spread footings on erodible soil are the most vulnerable (HEC-18).

## Movement: settlement, rotation, sliding

Signs include misaligned joints and rails, tilting columns, cracked backwalls, bearings at extreme positions, closed or opened expansion joints, and gaps between superstructure and backwall. Measure plumbness and joint openings and compare to previous reports. Progressive movement is more concerning than a one-time stable offset.

## Concrete and steel substructure deterioration

Concrete caps under leaking joints suffer chloride corrosion, cracking and spalling, especially at bearing seats. Steel H-piles corrode most at the splash zone and waterline; timber piles decay at the groundline and waterline. Pier columns in tidal zones may need underwater inspection. Record remaining section with dimensions.

## Scour and undermining

Probe around footings and piles; record channel cross-sections and compare over time. Exposed footings, undermining and exposed piles beyond design are serious. A scour appraisal is required for all bridges over water (23 CFR 650.313(o)) and observed scour feeds the scour condition rating. Substructure ratings must reflect undermining and loss of support.

## Connecting findings to rating and action

- Loss of pile section may require substructure load rating (MBE allows rating substructure where it may govern).
- Bearing seat spalls can reduce support length — check for adequate seat.
- Collision damage to piers needs prompt engineering evaluation.
- Report movement trends with measurements so engineers can decide on monitoring or repair.

## Part A — Learning objectives and how to use this course

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

- Identify the common substructure types (abutments, wingwalls, piers, bents, pile bents and foundations) and the role each plays in carrying load and resisting lateral forces.
- Recognize deterioration and distress in concrete, steel, timber and masonry substructure units, and relate each to its cause.
- Detect and measure movement: settlement, tilt, rotation, sliding and lateral displacement, and know why trends matter more than a single reading.
- Inspect bearing seats, caps and the superstructure-substructure interface, where many problems start.
- Recognize signs of scour and stream instability at the substructure and understand the NBIS scour appraisal and Plan of Action requirements.
- Quantify substructure elements by condition state, assign a defensible substructure rating, and know when to escalate.

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 (NBIS), FHWA HEC-18 (Evaluating Scour at Bridges), HEC-20 (Stream Stability at Highway Structures), HEC-23 (Bridge Scour and Stream Instability Countermeasures), FHWA's Underwater Bridge Inspection manual, ACI 345.1R and ACI 546R for concrete maintenance and repair, and the USDA Forest Service timber bridge manual by Ritter. Underwater inspection is covered in depth in BR-I09; this course focuses on what can be seen and measured above water and at low water, and on how the substructure behaves as a system.

## Part B — Substructure types and how they work

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### Abutments

Abutments support the ends of the superstructure and retain the approach fill. Common types include:

- **Full-height (cantilever or gravity) abutments:** tall walls retaining the full embankment height. They resist large earth pressures and are vulnerable to tilting, sliding and cracking from those pressures.
- **Stub or seat abutments:** short walls on top of the embankment or on piles, with the embankment sloping down in front.
- **Spill-through abutments:** columns or open frames with fill spilling through between them.
- **Integral and semi-integral abutments:** the superstructure is cast into or connected to the abutment without an expansion joint, so the abutment moves with thermal expansion and contraction. They avoid joint problems but can show approach slab and wingwall cracking from cyclic movement.
- **MSE abutments:** a bridge seat on or behind a mechanically stabilized earth wall.

### Wingwalls

Wingwalls retain the fill beside the abutment. They may be cast monolithically with the abutment or separated by a joint. Separation, tilting and cracking at the junction are common, and failure of a wingwall can lead to loss of embankment and undermining of the approach.

## Piers and bents

- **Solid wall piers**, common in streams because they align with the flow.
- **Multi-column piers or bents** with a cap beam, sometimes with a web wall between columns.
- **Hammerhead piers**, a single column with a cantilevered cap.
- **Pile bents**: piles extending above ground or water to a cap, common on shorter spans and in older timber and steel structures.
- **Straddle bents and integral steel caps**, which may be NSTMs if in tension and without redundancy.

## Foundations

Spread footings bear directly on soil or rock. Deep foundations transfer load through driven piles or drilled shafts. Foundation type and depth control how vulnerable the unit is to scour and settlement, so look them up in the plans before the field visit. Where plans do not exist, the NBIS treats bridges over water with unknown foundations specially in the scour provisions.

## Load paths

Every substructure unit carries vertical load from the bearings to the foundation and resists lateral loads from earth pressure, wind, braking, temperature movement, stream flow, ice, debris and impact. Distress tends to show where the load path concentrates: bearing seats, cap ends, column tops and bottoms, footings and pile-to-cap connections.

## Part C — Planning the substructure inspection

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Preparation pays off:

- Review plans for unit types, foundation type, footing elevations, pile tip elevations and design scour information if available.
- Review prior reports and photos, especially any tilt, settlement, scour or channel measurements, so you can repeat them.
- Check the bridge's scour appraisal and whether it is scour critical, and read the scour Plan of Action (POA) if one exists.
- Check streamflow conditions; a high-water visit may hide the very things you need to see.
- Plan access for caps and bearing seats (ladder, lift or snooper) and for the channel (waders, boat, probing rod).
- Bring a level or plumb bob, a 4 ft level or digital inclinometer, a probing rod, a sounding hammer, a tape, a camera and a crack card.
- Coordinate traffic control for piers in medians and along roadways, and follow the owner's water-safety rules.

## Part D — Concrete substructures: what to look for

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Most substructures are concrete, and the defect vocabulary from BR-I06 applies: cracking, delamination, spalling, efflorescence, scaling, honeycombing, abrasion, exposed reinforcement. The difference is where and why the defects appear.

### Bearing seats and caps

The tops of abutments and pier caps sit under the deck joints. When joints leak, chloride-laden water soaks the bearing seats and cap tops, and the result is delamination and spalling around bearings, sometimes undermining the masonry plates. Debris accumulation on the seat holds moisture against the concrete. Inspect the seats from close range, sound the concrete around

each bearing, and record any loss of bearing area. Look for cracking under bearings that may indicate high local stress or bearing restraint, and for cap cracking at the ends of hammerhead and multi-column caps where shear and moment are high.

## **Columns and walls**

Look for vertical cracking along bars with staining (corrosion), map cracking (possible ASR or freeze-thaw), and horizontal cracks that may indicate flexure or movement. On columns next to roadways, record impact damage, and on those in medians, record deterioration from salt spray and splash. Columns in water show abrasion and deterioration in the splash and tidal zones and at the waterline.

## **Footings**

Footings are usually buried, but they are exposed by erosion, scour or excavation. Exposed footings should be measured and described, and any undermining recorded with dimensions. A footing that was designed to be buried and is now exposed is itself a sign that the channel has changed.

## **Chemical attack**

Sulfates in soil or water and acidic water can attack concrete, softening the paste. Look for loss of surface, exposed aggregate and soft concrete at and below grade or the waterline. Recommend sampling where chemical attack is suspected.

## **Abutment walls**

Full-height walls show cracking from earth pressure, shrinkage and restraint. Diagonal cracks from the corners of the bearing seat, vertical cracks at regular intervals, and horizontal cracks can each mean different things. Map them and compare with past reports. Look for weep holes that are blocked, because poor drainage behind the wall raises the pressure on it. Efflorescence at construction joints and weep holes shows the water path.

# **Part E — Steel, timber and masonry substructures**

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## **Steel piles and bents**

Steel H-piles and pipe piles corrode most at the zone of fluctuating water levels and at the ground line, where oxygen and moisture are both present. Clean and measure flange and web thickness at those locations and look for holes, pitting, and buckling. Steel caps and bracing corrode under leaking joints. Bracing connections may be loose or broken. Record measured remaining section, because pile capacity is sensitive to loss in the flanges.

## **Timber piles, caps and bracing**

Timber is vulnerable to decay from fungi, insect attack, and marine borers in salt or brackish water. The USDA Forest Service manual on timber bridges (Ritter) describes inspection methods. Decay often begins inside the member where checks and bolt holes let water in, so a sound-looking surface may hide a hollow core. Use a sounding hammer to find hollow areas, and where the owner allows, use an increment borer or drilling to measure the shell thickness, plugging test holes with treated plugs afterward. Look closely at the ground line and waterline of piles, at the top of piles under caps where water collects, at cap-to-pile connections, and at bolted bracing. Record crushing of caps over piles, split caps, and loose or missing hardware. Marine borer damage at the mudline can drastically reduce section with little outward sign.

## Masonry

Stone and brick masonry abutments and piers remain in service on older bridges. Look for loss of mortar, displaced or missing stones, bulging, cracks running through stones and joints, and vegetation growing in the joints. Bulging and loss of stones near the base or waterline can signal undermining or loss of fill behind the wall. Record the location and extent of mortar loss and displacement.

## Part F — Movement: settlement, tilt, rotation and sliding

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Movement is the substructure finding that most often needs an engineer, and it is the one most easily missed if no one measures. Signs include:

- **Tilt:** an abutment, wingwall or pier leaning out of plumb. Measure with a plumb bob or digital level at marked locations.
- **Settlement:** a dip in the deck profile or rail over a pier or abutment, a bump at the end of the bridge, cracks in the substructure, or bearings that no longer seat evenly.
- **Rotation:** an abutment rotating forward at the top, often accompanied by closure of the expansion joint at that end or girders bearing against the backwall.
- **Sliding:** lateral displacement of an abutment or wingwall, often seen as misaligned joints, offset rails or opened wingwall joints.
- **Bearing evidence:** rockers tilted beyond what temperature explains, bearings walked off their pads, or girders resting on the backwall.

Measure, record and repeat. A single tilt reading of 1 in over 4 ft means little without knowing whether it was there in the as-built condition. A reading that has grown since the last cycle is meaningful. Use marked locations and the same tool every cycle, record the temperature and time when bearing position matters, and compare with the previous report in writing.

Movement can have many causes: scour or undermining, consolidation of soft soils, slope instability, high earth pressure from poor drainage, thermal ratcheting on integral abutments, or seismic events. Determining the cause is an engineering task, often needing survey data and geotechnical input. The inspector's job is to find it, measure it, and report it promptly.

## Part G — Scour and stream instability at the substructure

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Scour, the removal of streambed material around foundations by flowing water, is a leading cause of bridge failures in the United States. FHWA's hydraulic engineering circulars set the national practice: HEC-18 covers evaluating scour, HEC-20 covers stream stability, and HEC-23 covers countermeasures. The inspector is the eyes of that program between floods.

### Components of scour

- **Long-term aggradation and degradation:** the streambed rising or falling over years along a reach.
- **Contraction scour:** general lowering of the bed through a bridge opening narrower than the natural channel or floodplain.
- **Local scour:** holes around piers and abutments caused by the flow obstruction and the vortices it creates.

Lateral migration of the channel, a separate stream-stability process, can shift the main flow toward an abutment or a pier that was built on the floodplain.

## What the inspector looks for

- Exposed footings or piles, undermining, and holes at the upstream nose of piers and around abutment toes.
- Changes in channel cross-section compared with previous reports. Take soundings or probe at the same stations each cycle and record them on a cross-section sketch.
- Bank erosion, especially at abutments and on the outside of bends.
- Debris accumulation on piers, which increases the effective pier width and scour depth and adds lateral load.
- Riprap or other countermeasures displaced, missing, undersized or buried.
- Channel alignment changes relative to the bridge, and skew between flow and piers.
- Signs of movement at the substructure (Part F), which can be the first visible sign of foundation undermining.

Scour holes often refill as floods recede, so the bed after a flood may not show the maximum scour that occurred. Probing with a rod can reveal softer refill material. For this reason, inspections after significant floods, and monitoring during them under a POA, matter.

## NBIS scour provisions

The NBIS defines a **scour critical bridge** as a bridge with a foundation member that is unstable, or may become unstable, as determined by the scour appraisal (23 CFR 650.305). Owners must perform a scour appraisal for bridges over water and, for bridges determined to be scour critical or having unknown foundations, prepare and document a scour Plan of Action (POA) for deploying countermeasures and addressing safety concerns. The POA must address a schedule for repairing or installing physical or hydraulic countermeasures, or the use of monitoring as a countermeasure, and should be consistent with the HEC guidance. Inspectors need to know whether the bridge has a POA, what it requires of them (for example, monitoring after a given flow or rainfall), and what to do when a trigger is met.

## Ratings that interact with scour

The SNBI includes channel, channel protection, scour condition and scour vulnerability items. Under 23 CFR 650.311, a scour condition rated 3 or less requires shorter routine and underwater intervals, and under 650.313(q), channel or scour condition rated 2 or less is a minimum critical finding trigger. The substructure rating itself should reflect any loss of support caused by scour, even if the concrete or steel is in good condition.

## Countermeasures you may inspect

HEC-23 describes countermeasures such as riprap, gabions, articulating concrete blocks, grout-filled mattresses, spurs and bendway weirs, guide banks, and structural measures such as footing extensions or added piles. Inspect them for displacement, loss of material, undermining and whether they are still doing their job. A countermeasure that has failed may leave the foundation more exposed than it looks.

## Part H — Collision, ice, debris and other loads

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Piers next to roads and railroads are struck by vehicles; piers in navigable waterways may be struck by vessels or barges. Record spalls, cracking, exposed or bent bars, damage to protective systems (fenders, dolphins, crash walls or barriers), and any displacement of the unit. Impact can crack columns at the base or top where moments are high, so look away from the obvious damaged spot too.

In cold climates, ice floes abrade piers at the waterline and add lateral load. Debris rafts against piers during floods. Record debris size and location and recommend removal where it obstructs flow or loads the pier. Note any damage to pier noses or

ice breakers.

## Part I — Element quantities and the substructure rating

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The MBEI substructure elements include abutments, pier walls, columns, pier caps, pile caps and footings, piles, and wingwalls, by material, measured in linear feet or each as defined. Distribute the quantity of each element among the four condition states using the MBEI defect definitions: for concrete, cracking, delamination and spalling, exposed reinforcement, efflorescence, abrasion, and settlement or scour; for steel, corrosion, cracking and distortion; for timber, decay, checks and splits, and crushing; for masonry, mortar loss, split or spalled units and displacement. Owner guidance often adds detail.

The 0–9 substructure condition rating reflects the overall condition of all substructure units, considering severity, extent and structural significance. A single unit can control. For example, an otherwise sound bridge with one pier undermined by scour, or one pile with severe section loss at the waterline, can warrant a low substructure rating, because the consequence of that one unit failing is high. Conversely, scattered minor spalls on several units, with no loss of support, may support a fair or satisfactory rating. Ensure the narrative explains which unit controls the rating and why. BR-I05 covers the rating scale in detail.

Remember the interactions under the NBIS: a substructure rated 3 or less requires routine inspection at intervals not exceeding 12 months under Method 1 (650.311(a)(1)(ii)), and a substructure rated 2 or less is a minimum critical finding trigger (650.313(q)(1)(i)(C)).

## Part J — When to call the structural engineer

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Escalate immediately, following owner procedures, when you find:

- Undermining of a spread footing, or exposed piles beyond what the design anticipated.
- New or increasing tilt, settlement, rotation or sliding of any unit.
- Loss of bearing area at a seat that threatens support of a girder.
- Severe section loss or decay in piles, especially at the waterline or ground line.
- Cracked or crushed caps, or shear cracking in caps.
- A pier struck and damaged, with cracking at the base or displacement.
- Scour POA triggers met, or a countermeasure that has failed.
- Large debris loading a pier during or after high water.

Describe what you see, measurements and photos, traffic and waterway impacts, and what has been done. Document the escalation in the report and the owner's notification record. Substructure failures can happen quickly once support is lost, so do not wait for the report cycle to communicate them.

## Part K — Worked examples

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### Example 1 — Leaking joint over a pier cap

The cap of a three-column pier beneath a failed compression seal is wet, with efflorescence, rust staining and two spalls exposing corroded cap bars near bearings. Sounding finds hollow areas around three of five bearings. *Discussion:* Record the spall and delamination areas, the bar condition, and the bearing area affected at each bearing. Refer the bearing seat condition

for evaluation if bearing area loss is significant. The root cause is the joint; recommend sealing or eliminating it. Assign cap quantities to condition states and explain in the narrative how much the cap condition influences the substructure rating.

### **Example 2 — Abutment rotation**

At the north abutment of a two-span bridge, the expansion joint is nearly closed and the girder ends are close to the backwall. A plumb reading at a marked location shows the abutment face leaning forward more than in the previous report. The approach pavement has a new transverse crack behind the backwall. *Discussion:* The evidence suggests the abutment is rotating forward, possibly from earth pressure, poor drainage or foundation movement. Record all measurements and photos, check the weep holes, and refer it promptly to the engineer for survey and geotechnical evaluation. Note the joint opening and the temperature.

### **Example 3 — Timber pile bent**

A county bridge has timber pile bents. Several piles sound hollow at the ground line. One pile has visible crushing of the cap above it, and the bracing bolts are loose. *Discussion:* Sound each pile around its circumference and record hollow zones. Where allowed, bore to measure shell thickness. Record the crushing and loose hardware. Recommend engineering evaluation and repair options such as posting, pile replacement or splicing. If decay reduces section enough to affect capacity, the owner's load rating and posting procedures apply.

### **Example 4 — Exposed spread footing**

At low water, the upstream end of a spread footing on a river pier is exposed, and probing finds a void extending under the leading edge. The previous report recorded the footing as buried. *Discussion:* This is a scour finding with potential loss of support. Measure the exposed depth and the undermined dimension, sketch it, and photograph it. Notify the structural engineer immediately and follow the POA, which may call for closure, monitoring or countermeasures. Update the scour condition and channel items and make sure the substructure rating reflects the threat to support. Underwater inspection may be needed to define the extent (see BR-I09).

### **Example 5 — Steel H-piles in a tidal zone**

Steel H-pile bents in brackish water show heavy corrosion in the tidal zone. Ultrasonic readings at cleaned spots show flange thickness reduced by roughly a third of the original at several piles. *Discussion:* Record the measurements at each pile with location and elevation, sketch the remaining section, and refer to the load rater and engineer. Recommend repair options such as encasement or jacketing as an engineer specifies.

### **Example 6 — Masonry abutment with mortar loss**

A stone masonry abutment has mortar loss along many joints, a few displaced stones near the waterline, and vegetation growing from joints. *Discussion:* Record the extent and locations, check for bulging or loss of fill behind the wall, and look for undermining at the base. Recommend vegetation removal and repointing, and an engineering evaluation if stones are displaced near the base.

## Part L — Integral abutments, MSE walls and approaches

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### Integral and semi-integral abutments

Integral abutments eliminate the deck expansion joint, which removes the single biggest source of substructure deterioration. The trade-off is that the abutment and its piles move with the superstructure as temperature changes. Inspectors should look for cracking at the junction of the abutment and wingwalls, cracking or settlement of the approach slab, a gap or bump at the end of the approach slab where the movement is accommodated, and erosion of the fill near the abutment. Cracking at the backwall-to-deck connection is common and should be recorded so that trends are visible. Because there is no joint, any water reaching the abutment comes from elsewhere, such as the approach slab joint or poor drainage, so trace it.

### MSE walls at abutments

Where the bridge seat sits on or behind a mechanically stabilized earth wall, inspect the wall facing for bulging, panel misalignment, cracked or spalled panels, open joints with fill loss, and settlement of the coping. Fill washing out of joints suggests drainage problems or failed joint filter fabric. Deformation of the facing near the bridge seat can indicate movement of the reinforced fill. Record measurements and refer significant changes for geotechnical review.

### Approach and embankment

Although the approach roadway is not part of the substructure, it often reveals substructure behavior. A growing bump at the end of the bridge, settlement of the approach slab, cracking of the slab or pavement, and erosion of the embankment beside the wingwalls can all reflect movement or loss of fill. Inspect slope protection under the bridge end for erosion, voids and undermining.

## Part M — Preservation and repair options

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As with superstructures, many substructure problems are cheapest to fix at the source. FHWA's Bridge Preservation Guide lists actions such as cleaning bearing seats and caps, sealing or eliminating joints, applying penetrating sealers to splash zones, clearing debris and vegetation, and maintaining weep holes and drainage. Typical repairs, which an engineer designs and specifies, include:

- Concrete patching of caps, columns and walls following ACI 546R practice.
- Column jacketing or encasement where section loss or corrosion is extensive; FRP wraps may be considered under ACI 440.2R.
- Steel pile encasement, jacketing or plating, or pile replacement.
- Timber pile posting, splicing or replacement, and cap replacement.
- Repointing and stone replacement on masonry.
- Scour countermeasures selected from HEC-23 options, and restoration of failed riprap.
- Foundation underpinning or added piles where support is threatened.

Write recommendations that say what, where and how urgent, so they can be prioritized and tracked.

## Part N — Documentation that makes trends visible

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Substructure movement and scour are judged by change, so a substructure report should be built for comparison:

- Establish and reuse marked measurement locations for plumb, level and crack readings, and give them names in the report.
- Keep a channel cross-section at the upstream and downstream faces, or at the stations the owner uses, with soundings measured from a fixed reference such as the top of rail or deck edge. Plot each cycle on the same sketch.
- Photograph each unit from the same vantage points every cycle, including the upstream nose of each pier at low water.
- Record water level, flow conditions and the date of the most recent significant flood if known.
- Record bearing positions with the temperature.
- State limitations: high water, debris, vegetation or access that prevented seeing part of a unit.

When a reviewer can lay the last three cycles side by side and see what changed, the report has done its job.

## Part O — Frequently asked questions

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### **The substructure looks fine but the scour condition is poor. How do I rate the substructure?**

The substructure rating should reflect the condition of the units, including any effect of scour on their support. If scour has undermined a footing, the substructure rating should reflect the threat even if the concrete is sound. Channel and scour items are recorded separately, and the narrative should connect them.

### **Can I tell whether a scour hole is getting worse from one visit?**

Rarely. Compare with previous soundings at the same stations, and remember that holes refill after floods. Probing helps identify soft refill.

### **What if I cannot see the footing because of water?**

Note the limitation and probe where possible. If the substructure below water cannot be inspected visually at low water or by wading or probing, it falls within the NBIS definition of an underwater inspection, which follows its own interval and procedures (BR-I09).

### **Do integral abutments need less inspection?**

They need different inspection. They avoid joint leakage, but cracking, approach slab issues and pile behavior still need attention.

### **Is this course NBIS refresher training?**

No. LoadPath PDH courses are supplemental PDH and are not FHWA-approved training under 23 CFR 650.309.

## Part P — Summary checklist and glossary

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- Know each unit's type and foundation before the visit.
- Inspect bearing seats and caps closely; follow the water from the joints.
- Sound concrete, measure steel, sound and bore timber, and check masonry joints.
- Measure tilt, settlement and bearing position at marked locations and compare with prior cycles.
- Probe and sound the channel at fixed stations; look for undermining, debris and failed countermeasures.
- Know the scour appraisal and POA, and act on POA triggers.
- Rate the substructure on the controlling unit and explain it.

- Escalate loss of support, new movement and severe section loss immediately.

**Glossary.** *Scour critical bridge:* a bridge with a foundation member that is unstable, or may become unstable, as determined by the scour appraisal. *Scour POA:* procedures for managing a scour critical bridge, including countermeasures and monitoring. *Local scour:* scour around a pier or abutment from flow obstruction. *Contraction scour:* bed lowering across a constricted opening. *Undermining:* removal of support from beneath a footing. *Integral abutment:* an abutment built monolithically with the superstructure, without an expansion joint.

## Part Q — Inspections after floods, earthquakes and other events

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The NBIS defines a **damage inspection** as an unscheduled inspection to assess structural damage resulting from environmental factors or human actions (23 CFR 650.305). Owners also use **special inspections** to monitor known or suspected deficiencies. After floods, earthquakes, impacts and fires, substructure units are often the focus.

### After a flood

Follow the POA where one exists. Look for debris on piers, new bank erosion, displaced riprap, newly exposed footings or piles, and any sign of movement such as a sag in the deck or rail over a pier. Remember that scour holes may have refilled. Compare soundings with previous cycles, and recommend an underwater inspection when the foundation cannot otherwise be checked.

### After an earthquake

Look for cracking and spalling at column tops and bottoms where plastic hinging can occur, shear cracking in columns and caps, displacement at bearings and seats, unseating of girders, damage to restrainers and shear keys, abutment backwall damage, and settlement or spreading of approach fills. Owners in seismic regions have specific post-earthquake procedures; follow them, and report any loss of support immediately.

### After an impact or fire

Look beyond the visible damage: check column bases and tops, the cap, the bearings and the superstructure above for related cracking or displacement. Fire can damage concrete by spalling and by reducing strength near the surface; recommend testing where the exposure was severe.

## Part R — More worked examples for self-check

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### Example 7 — Debris raft on a pier

After a storm, a debris raft of logs and brush spans most of the upstream face of a two-column pier, extending below the water surface. *Discussion:* Debris increases the effective pier width, which increases local scour and lateral load. Record its size and location, check for movement of the pier, recommend prompt removal, and recommend checking the bed around the pier after removal, possibly by underwater inspection.

### Example 8 — Wingwall separation

The joint between an abutment and its wingwall has opened at the top compared with the last report, and the wingwall leans away from the abutment. Fill has washed out from behind the joint. *Discussion:* Measure the opening and lean at marked

locations and compare. Check drainage and weep holes behind the wall. Recommend evaluation; loss of the wingwall can lead to embankment loss next to the abutment.

### Example 9 — Stable conditions

The channel soundings at both pier faces match the previous two cycles within the accuracy of the method, the riprap is intact, and the plumb readings are unchanged. *Discussion:* Record this explicitly. "Channel cross-section at upstream face matches 2022 and 2024 soundings; riprap intact; pier 2 plumb unchanged at marked location" is evidence the owner can use to support the scour appraisal and the interval.

## Part S — Reviewer's checklist for substructure findings

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Engineers who review substructure findings can ask:

1. Does the report name the unit that controls the substructure rating, and explain why?
2. Are tilt, settlement and bearing position measured at marked locations and compared with previous cycles?
3. Is there a channel cross-section with soundings from a fixed reference, compared with prior cycles?
4. Are the scour appraisal, the POA status, and any POA actions taken addressed?
5. Are pile section loss, timber decay and bearing-seat losses measured, not just described?
6. Are causes identified, such as leaking joints, blocked weep holes or debris?
7. Were urgent findings escalated, and is the escalation documented?
8. Are inspection limitations stated, such as high water or inaccessible footings?

A report that answers these questions lets the owner manage the bridge between inspections instead of being surprised by the next flood.

## Part T — The bearing seat: where superstructure meets substructure

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The bearing seat deserves its own section because it is where the superstructure's load, the deck's leakage and the substructure's movement all meet. Problems here are frequent and can be consequential.

### What to check at every seat

- **Seat width and edge distance:** how far the bearing or girder sits from the edge of the seat. Movement of the substructure, bearing walking or seat spalling can reduce this distance. Record it with a tape at each bearing where the owner's procedures call for it.
- **Concrete under the masonry plate or pad:** sound it, and look for cracking radiating from the bearing, spalls at the seat edge and crushing.
- **Anchor bolts:** bent, sheared or corroded bolts suggest restraint or movement beyond what the bearing allows.
- **Debris:** soil, sand, bird debris and vegetation on the seat hold moisture and salt; record it and recommend cleaning.
- **Bearing condition and position:** tie the observation to temperature, as in BR-I07.
- **Backwall and girder ends:** contact between girders and the backwall, or a closed joint, signals abutment movement or a restrained structure.

## Why it matters

Loss of seat width can, in extreme cases, lead to a girder losing support. Seat deterioration also influences bearing performance, and frozen or restrained bearings induce forces that crack caps and seats. A clear record of seat conditions lets an engineer decide whether to repair the seat, replace bearings, add seat extensions or install restraint, and when.

## Part U — Field note examples: weak versus strong

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*Weak:* "Pier 2 has some scour. Monitor."

*Strong:* "Pier 2, upstream nose: local scour hole approximately 2.5 ft deep below the adjacent bed, measured by probing from the deck edge reference at Station 3; footing top exposed for 4 ft along the upstream face; probing found no void under the footing edge. 2024 sounding at Station 3 showed the bed 1.5 ft higher. Riprap displaced downstream. Photos 41–44. Engineer notified 10:20 AM ET; POA reviewed; recommend underwater inspection and riprap restoration."

*Weak:* "Abutment leaning."

*Strong:* "North abutment face: 4 ft digital level at marked location NA-1 reads 1.3 degrees out of plumb toward the span (2024: 0.8 degrees at the same mark). Expansion joint opening 3/8 in at 58 F (2024: 1 in at 61 F). Two of four weep holes blocked. Photos 12–16. Referred to bridge engineer for survey and geotechnical review."

The strong notes give location, measurement, method, comparison, cause, photos, escalation and recommendation. They take a few more minutes to write and save hours of follow-up later. The numbers in these examples are illustrative only; your report should use what you actually measure.

## Part V — Self-check questions before the quiz

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Work through these before taking the quiz. Each one draws on several parts of the course, and none has a single number for an answer. Write a sentence or two for each, as you would in a field note, then check your reasoning against the parts listed after the questions.

1. A pier looks sound, but the channel soundings show the bed at its upstream face has dropped since the last cycle. What do you record, what ratings may be affected, and whom do you notify?
2. An integral abutment has a new crack at the wingwall junction and the approach slab has settled. Where else would you look, and why is there no deck joint to blame?
3. A timber pile sounds solid on the surface but has a bolt hole near the ground line with dark staining. What further check would you request, and what are you worried about?
4. Rockers at an expansion pier are tilted toward the span on a cool morning. What does the temperature tell you, and what else would you check at that pier and the abutment at the far end?
5. Steel piles in a tidal zone show heavy rust. What measurements would make your finding useful to the load rater?
6. After a flood, the bed around a pier looks normal. Why might that be misleading, and what would you do?
7. Which unit controls the substructure rating on a bridge with three sound piers and one abutment with a scour-undermined footing, and why?

Suggested answers draw on Parts F (movement), G (scour), E (timber and steel), I (ratings) and T (bearing seats). If you can answer each of these with a measurement plan, a rating consequence and an escalation step, you have the core of this course.

## Closing thought

Abutments, piers and bents carry everything above them, yet they are often the least-visited parts of a bridge. Substructures rarely fail without warning, but the warnings are quiet: a hole that refills, a joint that slowly closes, a pile that sounds a little hollow. Measured, repeatable observations turn those quiet warnings into evidence an engineer can act on. Take the time to measure, mark and compare, and the substructure will usually tell you what it is doing.

## Key takeaways

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- Know foundation type — spread footings are most scour-vulnerable.
- Look for movement trends: tilts, joint gaps, bearing positions.
- Steel piles corrode at splash zones; timber decays at groundline.
- Undermining and section loss feed ratings and critical findings.

## References

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5. 23 CFR Part 650, Subpart C — National Bridge Inspection Standards (final rule published May 6, 2022)
6. FHWA, HEC-20 Stream Stability at Highway Structures, 4th Edition, FHWA-HIF-12-004, 2012
7. FHWA, HEC-23 Bridge Scour and Stream Instability Countermeasures, 3rd Edition, FHWA-NHI-09-111 and -112, 2009
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13. FHWA, Bridge Preservation Guide: Maintaining a Resilient Infrastructure to Preserve Mobility, FHWA-HIF-18-022, 2018

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