PE

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Bridge Engineering in Practice: Planning, Design Coordination, Construction & Preservation

An integrated project-to-preservation course for practicing engineers

6 Professional Development Hours • Self-paced engineering education • November 2026 edition

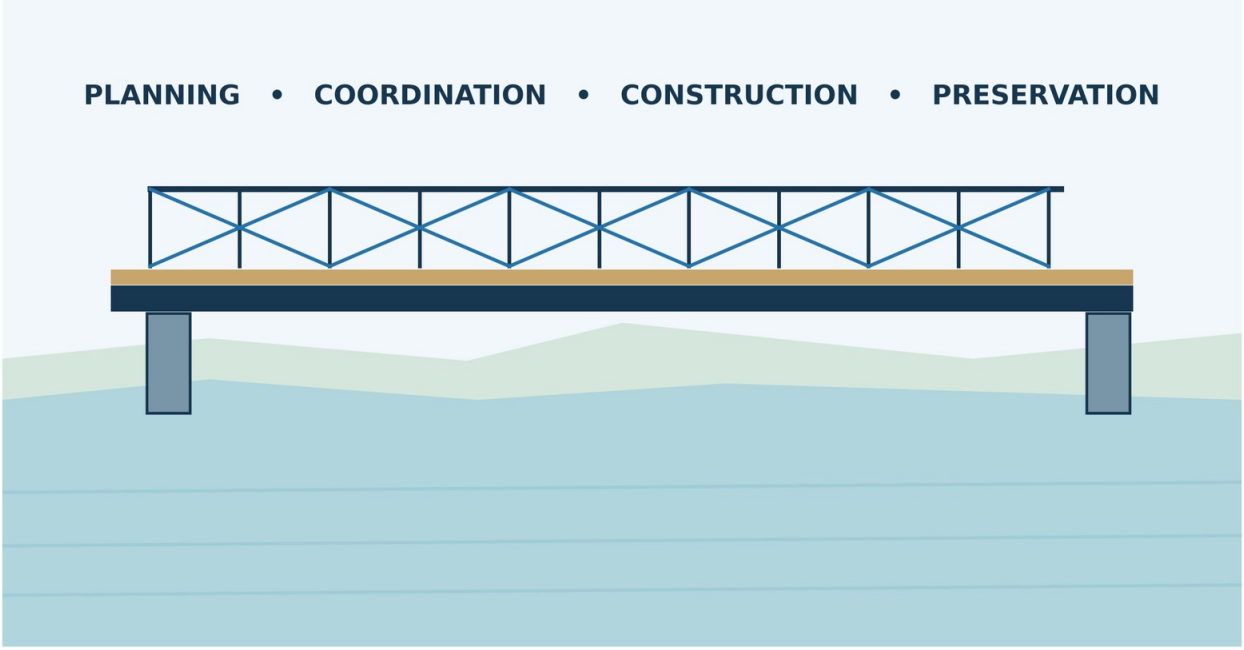


Figure Cover. Conceptual illustration of a steel bridge over a waterway; no dimensions or structural details are implied.

The bridge engineering process connects early facility planning, technical design interfaces, safe construction, documented quality and long-term preservation. The material emphasizes practical professional decisions and integrated engineering communication rather than memorization of isolated formulas.

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How to use this course

The six modules use a single integrated learning path. Read each module, study its technical diagrams, complete the applied engineering worksheet, and use the closing five-minute consolidation period to check your reasoning against the stated decision criteria. The project scenarios and numerical examples are fictional teaching cases. Where calculations are simplified, their assumptions are explicit. Use only project-adopted standards, local agency requirements and qualified engineering review for actual bridge design, construction, inspection and repair.

This course is not a structural-design specification, a substitute for project-specific calculations, or qualification for NBIS bridge-inspection roles. Public bridge inspection and load rating are governed by applicable program requirements. Project contract documents, authorized engineering decisions and adopted standards control actual work. The multiple-choice completion assessment is administered separately from this learning text.

Learning outcomes

1. Explain primary bridge systems, structural load paths, movements, and the relationships between superstructure, bearings, substructure and foundations.

2. Screen bridge project alternatives using function, geometry, hydraulics, geotechnical information, environmental constraints, construction access and long-term ownership costs.

3. Manage design interfaces and conduct a practical constructability review without substituting for project-specific structural analysis or checking.

4. Identify quality-control hold points and document appropriate construction responses when fabrication, erection, concrete work or site conditions deviate from requirements.

5. Interpret observed deterioration and inspection information as evidence that supports, but does not itself establish, structural capacity.

6. Differentiate maintenance, preservation, rehabilitation and replacement and select defensible interventions using condition, risk and service-life considerations.

7. Prepare an integrated decision record communicating assumptions, unresolved interfaces, responsible parties and the next authorized action.

8. Apply these concepts to an integrated hypothetical bridge project and explain which project decisions must be referred to qualified specialists or owner authorities.

Open technical sources and edition control

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Instructional time allocation

Module	Topic	Reading and diagrams	Applied work	Consolidation	Total
1	Bridge fundamentals: systems, actions and interfaces	25 min	15 min	5 min	45 min
2	Planning, approvals and project development	30 min	25 min	5 min	60 min
3	Design coordination, constructability and detailing	35 min	35 min	5 min	75 min
4	Construction, fabrication and quality assurance	35 min	35 min	5 min	75 min
5	Condition assessment and deterioration mechanisms	25 min	30 min	5 min	60 min
6	Preservation strategy and lifecycle decisions	20 min	20 min	5 min	45 min
	Total	170 min	160 min	30 min	360 min

The allocated duration includes guided review of dense engineering content and completion of written engineering exercises; it is not a claim that reading the document alone takes six hours. Program administrators should verify the proposed PDH allocation against the applicable approval and completion rules before issuance of credit.

Module sequence

Module 1: Bridge fundamentals: systems, actions and interfaces | 45 minutes

Module 2: Planning, approvals and project development | 60 minutes

Module 3: Design coordination, constructability and detailing | 75 minutes

Module 4: Construction, fabrication and quality assurance | 75 minutes

Module 5: Condition assessment and deterioration mechanisms | 60 minutes

Module 6: Preservation strategy and lifecycle decisions | 45 minutes

Applied engineering worksheets

Glossary of practice terms

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MODULE 1 | Bridge fundamentals: systems, actions and interfaces

45 minutes • Reading/diagram analysis 25 min • Applied worksheet 15 min • Consolidation 5 min

The bridge is a system of load transfer, controlled movement and exposure—not a collection of independent details.

1.1 Bridge system boundaries

A bridge project begins with a precise statement of what the structure must carry and what it must cross. Highway, railroad, pedestrian and shared-use crossings can share geometry and materials while differing materially in loading, user protection, accessibility, fatigue demand and governing criteria. Establish the owner, facility function, design life objectives, legal jurisdiction, route classification, emergency-access needs and design basis before comparing structural options. An apparently simple trail crossing can present demanding vibration, railing, flood, access and long-term maintenance questions. A highway crossing may be dominated by traffic staging rather than maximum span.

Organize the physical bridge into deck and wearing surface, superstructure, bearings and expansion accommodation, substructure, foundations and approaches. The approach embankment and drainage system influence bridge performance even when they are outside the structure's nominal limits. Expansion joints admit water if they fail. An undersized approach drain can direct runoff toward bearings. A misplaced utility support can impair inspection access. A project team that treats these as separate contracts needs an explicit interface register to stop important obligations from falling between parties.

Begin a systems walkdown at the deck surface and trace every significant demand into the ground. Traffic, pedestrian loading, wind, temperature, braking, stream forces and seismic effects have different paths and may govern different components or combinations. The point is not to memorize all factors. The point is to identify what is transferring forces, which elements permit movement, and what would change if a component is blocked, removed or deteriorated.

1.2 Load path and continuity

A simple-span girder develops reactions at its supports. The deck distributes load into longitudinal members, which transfer forces through bearings to seats or caps, piers or abutments, foundations and supporting soil or rock. A continuous superstructure has a different distribution of positive and negative bending and may develop sensitivity to settlement and restraint. Diaphragms and cross-frames provide bracing and transverse system behavior; they should not be described merely as pieces that hold girders apart. Connections are interfaces in the force path and can be significant fatigue locations.

Consider a conceptual two-girder span supported at both ends. A uniformly distributed 90-kip service load on a simply supported beam produces nominal end reactions of 45 kips each by equilibrium if self-weight and other effects are already included in the total. This is not a bridge design calculation: load distribution, eccentricity, structural continuity, bearing orientation, applicable load combinations

and resistance checks require governing project methods. The example demonstrates why a support change cannot be evaluated as a local geometry correction without assessing force transfer.

In a continuous unit, a damaged bearing or a fixed point at the wrong location can alter restraint and thermal stresses even without obvious girder deformation. Design coordination therefore records which support is intended to move longitudinally, transversely or rotationally, and which construction stages or temporary restraints are allowed. A project should never infer that an unlabeled support is free or fixed based solely on its physical appearance.

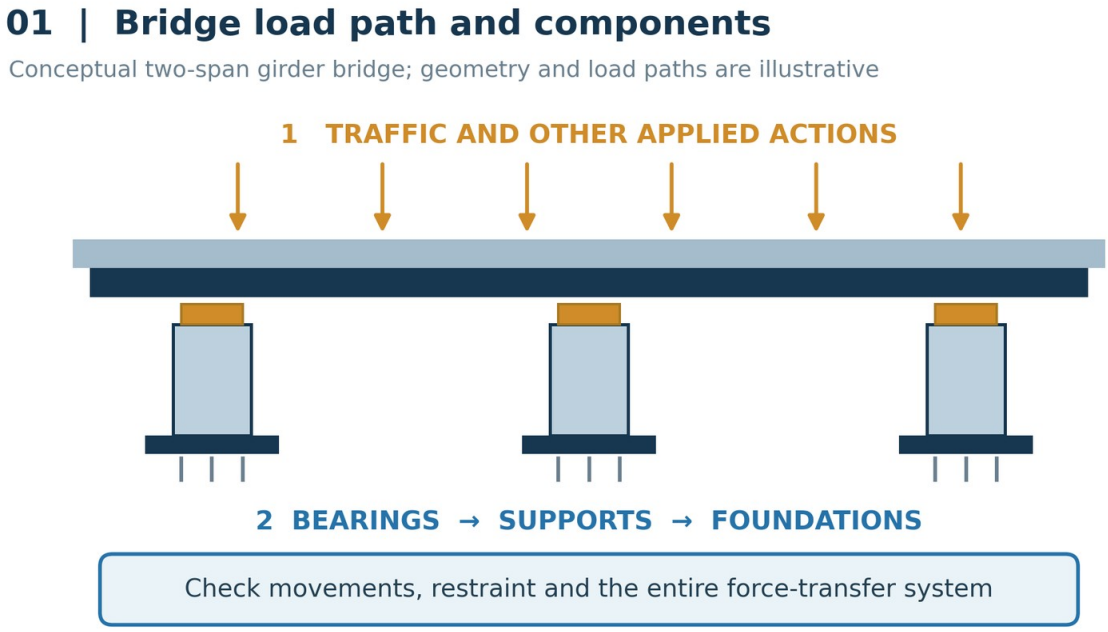


Figure 1. The main structural load path is deck to girders to bearings to supports and foundations.

1.3 Movements, serviceability and user experience

Bridges experience temperature change, shrinkage, creep, deflection, rotation, settlement and, where relevant, seismic displacement. A joint or bearing detail must accommodate anticipated movements, and the attached drainage or utility system must tolerate the same range. Serviceability also includes deck drainage, pedestrian comfort, approach transitions, railing continuity, vehicle clearance, skid resistance and long-term ride quality. Expansion accommodation may be distributed throughout jointless or integral systems rather than placed at every end; the design concept determines where movement is taken.

Use the elementary relation $\Delta L = \alpha L \Delta T$ only as a first screening calculation. For a hypothetical 120-ft steel component, $\alpha = 6.5 \times 10^{-6}/°F$, and a 90°F temperature change, ΔL is about 0.084 ft or 1.01 in. The selected α and change are hypothetical exercise assumptions, not prescriptive bridge design values. Actual movement estimates also consider thermal reference state, restraint, deck composite behavior, other time-dependent actions and the applicable specification. The designer needs a documented movement schedule rather than a single unqualified calculation.

A trail bridge adds human-induced vibration considerations. A bridge that meets ultimate strength requirements may still be uncomfortable. Avoid implying that vibration acceptance can be determined from a simple span-to-depth rule: dynamic characteristics, participation and accepted owner criteria govern the review. The practical lesson is to identify serviceability questions early enough to change the concept rather than attempt to treat them as cosmetic issues in final detailing.

1.4 Bridge families and consequence of type selection

Common choices include precast prestressed concrete girders, cast-in-place concrete systems, steel plate girders, weathering-steel or coated steel systems, trusses, arches and specialty pedestrian systems. Feasible selection depends on span, curvature, skew, construction access, available depth, shipping envelope, erection method, material availability, inspection access and local contractor capability. A low initial material cost can be outweighed by temporary works, closures, coating access, future joint replacements or complex fabrication. Type selection is a decision under constraints, not a catalog ranking.

For a single crossing, a precast option may reduce on-site forming but increase crane and delivery constraints. A fabricated steel option may serve long spans and difficult clearances but require detail-level coordination on lift points, cross-frame fit-up, weld access and coating. Cast-in-place concrete may suit geometry yet demand extended curing, falsework and water-management measures. Record not only the preferred type but why alternatives were rejected and what event could change the conclusion. This allows new geotechnical or permitting information to reopen a decision without losing the reasoning behind it.

Bridge type also establishes a maintenance burden. Narrow boxed regions, inaccessible bearings, water traps, unsealed details and complex drainage impose inspection and preservation costs. An economical project-level decision identifies the anticipated exposure environment, access to vulnerable details and a credible intervention path. The owner should be able to reach and maintain the feature it is asked to accept.

1.5 Read the plans as a coordinated system

A useful drawing review follows an assembly sequence: general notes and criteria; alignment and profile; span arrangement; foundations; substructure; superstructure framing; deck and approach details; temporary works assumptions; drainage, utilities and environmental constraints; and construction staging. Checking only the bridge general plan misses mismatches between roadway grade and bridge seat elevations, utility crossings and girder diaphragms, or temporary access and the floodplain. The interface register assigns each issue a drawing reference, potential consequence, owner and due date.

Separate a confirmed requirement, an engineering assumption and an open question. For example, a preliminary horizontal clearance shown on an alignment drawing may be a design assumption, whereas a railroad owner may require a formal approval of clearance. The distinction determines whether a contractor can reasonably proceed or whether the design cannot be released. Revision control matters because an interface resolved in email is not complete until incorporated into the governing record and communicated to affected teams.

An effective early bridge review is a coordinated conversation among structural, roadway, hydraulic, geotechnical, environmental, utility, traffic-control and construction specialists. It does not ask each discipline to issue independent approvals and hope the details align. It identifies the handful of physical interfaces where a decision in one discipline changes the feasible solution in another.

1.6 Worked example: trace restraint before calculating thermal movement

An engineer receives a plan view of a three-span bridge with a single fixed longitudinal restraint point at the central pier and guided bearings at adjacent supports. The bridge is continuous across the two interior supports. A utility hanger attaches at an end cross-frame. The roadway designer asks whether the bridge can accommodate a proposed 1.5-inch movement joint without changing utility details. The question cannot be answered by checking the gap dimension alone. The first step is to identify the datum for movement: where is the fixed point, what movements are expected at each end, how is the bridge erected and at what reference temperature are the joint openings set?

Take a simplified 240-ft total continuous structural length with a fixed location at the midpoint. Each end is 120 ft from that restraint. Assuming only free thermal elongation, $\alpha = 6.5 \times 10^{-6}/°F$ and $\Delta T = 90°F$, screening expansion at each end is $120 \times 12 \times 6.5 \times 10^{-6} \times 90 = 0.842$ in. A fixed point incorrectly assumed at the west abutment would suggest roughly 1.68 in of free movement at the east end, a different result for the same total span. This is why restraint layout must precede a movement estimate. The simplistic model omits rotation, creep/shrinkage, nonlinear support behavior, construction temperature and the movement assumptions adopted by the designer. It is not a design check.

The utility may respond to deck motion differently from the structure. A rigid hanger at the end cross-frame could transfer displacement into a utility connection even if the joint itself has enough physical gap. The correct interface record identifies utility support details, required flexibility, lateral and longitudinal allowances, maintenance access, agency approval and testing requirements. The roadway designer's original question is reframed as a coordinated movement and utility compatibility review rather than a single joint-capacity approval.

An owner-facing decision record would state: (1) bearing layout is confirmed from the structural model and drawings, (2) preliminary thermal movement is a screening estimate only, (3) the design professional must issue the approved movement schedule, (4) utility engineering must confirm flexibility and restraint compatibility, and (5) joint selection follows acceptance of both requirements. The sequence demonstrates how a small apparent detail can connect the deck, substructure, utilities and operation. It also shows why a field dimension should never become a substitute for an engineering assumption that has not been validated.

1.7 Field observation: distinguish geometry from behavior

Suppose a field team reports that the west expansion joint appears narrower at sunrise and wider during a hot afternoon. That observation is consistent with thermal movement, but it is not evidence that the joint or bearing is performing within specification. A competent record includes ambient and structural temperatures where available, bridge location, date/time, consistent measuring points, photographs, and prior baseline settings. Differences in traffic, deck shading or approach condition

can affect the apparent opening. A repeatable measurement process permits trends to be compared without pretending every measured change is a failure.

The same discipline applies to support observations. A cracked keeper plate, uplift mark, or unusual bearing displacement should prompt documentation and authorized investigation; it should not be immediately "reset" in the field. The as-found condition may be the only evidence of a restraint or movement problem. Engineering practice improves when observations preserve cause information rather than simply make the bridge look normal again.

Module 1 | Applied engineering workshop

System-tracing exercise (15 minutes). A conceptual two-span steel bridge carries local traffic across a tidal creek. The deck has a longitudinal expansion joint near the west approach, two pier bearings with unspecified lateral restraint, drainage outlets above the end cross-frame, and a gas utility proposed beneath the shoulder. On a sketch, trace vertical forces from deck to foundation; circle three features requiring movement or restraint coordination; list two ways runoff might reach vulnerable steel; and assign an owner to each unresolved interface. Prepare a five-line decision record distinguishing facts from assumptions. **Facilitator check:** a complete response recognizes load path, restraint, drainage, utility clearance and accessible inspection paths without inventing final dimensions.

Five-minute consolidation

Mark the primary force-transfer path and the support movements on your system sketch. For every unresolved utility or drainage interface, write who can confirm the assumption before detailing proceeds.

Technical reference pointers

Related source entries: [1], [4].

MODULE 2 | Planning, approvals and project development

60 minutes • Reading/diagram analysis 30 min • Applied worksheet 25 min • Consolidation 5 min

Plan for the crossing, its site constraints and its owner before fixing the span arrangement.

2.1 Define the service need before the bridge type

The project purpose is more useful than a premature material preference. Record whether the problem is route continuity, safety, hydraulic opening, maintenance access, inadequate capacity, flood resilience, accessibility or the replacement of an aging asset. Quantify the facility's operating context: traffic and freight requirements, pedestrian demand, planned utility corridors, emergency response, future widening and acceptable closure periods. Where a location has a prior bridge, obtain the inspection history and repair chronology; these records may reveal recurring causes such as debris impact, drainage failure or inaccessible joints.

Distinguish minimum performance criteria from preferences. A minimum required navigation or roadway clearance may be a gate; low-maintenance materials may be a weighted preference. A

feasible option must pass the gates before its weighted merits are compared. The comparison should expose unresolved data rather than conceal it in a composite score. Document who is authorized to approve changes in functional classification, geometric criteria or user experience expectations.

For a public project, the concept decision also controls permitting, public engagement and temporary traffic strategy. An apparently inexpensive replacement requiring a year-long route closure may be unacceptable to the owner; a slightly longer span that avoids work in a waterway may reduce environmental risk. The study must connect choices to construction realities and expected service rather than treating feasibility as a purely structural selection.

2.2 Establish the physical site model

Acquire survey, utilities, traffic and right-of-way information alongside reconnaissance, existing plans, inspection records and available geotechnical data. A location-specific ground model describes stratigraphy, groundwater, scour potential, settlement, constructability and known uncertainties. Do not extrapolate a nearby boring across a channel as if it proves the foundation at the proposed pier. Identify what the current investigation can support and what additional borings, tests or geophysics are needed before final foundation selection.

The waterway model addresses flood frequency, design storms or events, backwater, overtopping, debris, flow alignment, channel migration and scour. FHWA HEC-18 offers methods for assessing scour, but selecting and applying them requires qualified hydraulic and geotechnical work. A minimum opening based only on average water level can fail during floods even when ordinary flow appears benign. The designer should understand how pier location, skew, abutment geometry and approach fill affect the hydraulic system.

A site model also includes maintenance and staging access. A foundation system may be technically feasible yet require equipment or temporary trestles that cannot be permitted or supported by the site. By recording design, construction and access constraints on one concept plan, the team can distinguish a bridge alternative that is intrinsically infeasible from one that becomes feasible after a change in access or staging.

2.3 Approvals are a dependency chain

Environmental and permitting requirements vary by location, sponsor and work scope. They can include NEPA-related federal-aid processes, Clean Water Act authorizations, Section 404/401 coordination, threatened-species consultation, coastal constraints, waterways and navigation review, floodplain authorization, cultural resources and local land-use requirements. Not every project requires every permit, and identifying a potential trigger is not itself a permit determination. Assign a specialist to confirm applicable authorities, consultation steps, submittal data and lead times.

A permit may constrain work windows, pier placement, access, dewatering, turbidity control, species protection or sediment management. These are design inputs. If a conceptual span relies on a seasonal waterway closure, identify that assumption before the schedule is committed. Place permit milestones beside design milestones; a 90% design package that depends on unresolved permit geometry is not truly 90% for construction.

Approval tracking should distinguish: required, jurisdiction confirmed, application prepared, application submitted, issued, conditions incorporated, and closeout/monitoring required. A verbal discussion or preapplication meeting does not equal final authorization. Where the project modifies an existing crossing, also identify whether existing permits, easements or asset owner agreements remain applicable.

2.4 Scour, resilience and emergency operations

Bridge vulnerability is shaped by consequence as well as likelihood. Recurrent debris accumulations, tidal reversal, vessel or vehicle impact, wildfire, seismic exposure, flood isolation and alternate-route length can justify additional design attention even where ordinary load demand is modest. Separate the estimated physical exposure from the service consequence. A local trail crossing and an essential freight link can have similar hazards but very different closure consequences.

A resilience discussion identifies whether the asset can withstand an event, be inspected promptly afterward, and return to service within an owner-defined period. The team should map critical access points and likely failure modes rather than use an unsupported resilience score. For waterways, reconcile bridge elevation, approach overtopping, foundation protection, debris passage and maintenance provisions. A large hydraulic opening does not eliminate the need to evaluate scour at local foundations.

A risk register becomes operational when each risk is linked to a trigger and a response: high water observed at a specific benchmark activates inspection; unexpected foundation material prompts a changed-condition review; a utility conflict prevents excavation; or a permit delay changes the procurement path. Generic risks without a decision owner and response date rarely affect the project in time.

2.5 Concept comparison and lifecycle cost

Prepare a concise alternative matrix with at least the following dimensions: functional compliance, construction duration and closure, hydraulic and foundation uncertainty, environmental impacts, utilities, fabrication/transport constraints, routine access and maintenance, probable capital cost, and service-life cost. A rating such as “low, medium, high” must have documented reasons; it is not an objective mathematical result. Keep disqualifying conditions separate from preferences, and record what additional information could reverse the recommendation.

Lifecycle economics combine capital investment, expected maintenance and rehabilitation, user disruption, expected service life and residual value when applicable. For a comparison over a common study period, discount future cash flows using the public owner's adopted economic assumptions and perform sensitivity analysis on intervention timing and cost. Do not use an invented discount rate as a normative engineering requirement. Costs differ between current dollars, constant dollars and discounted value; keep the basis consistent.

At the end of planning, the bridge concept should have a configuration, a documented design-basis list, an interface/risk register, a permitting path and a schedule that retains the key uncertainties. Scope freeze does not mean all unknowns have disappeared. It means the parties understand which

assumptions have been accepted and what change-control process applies if later evidence contradicts them.

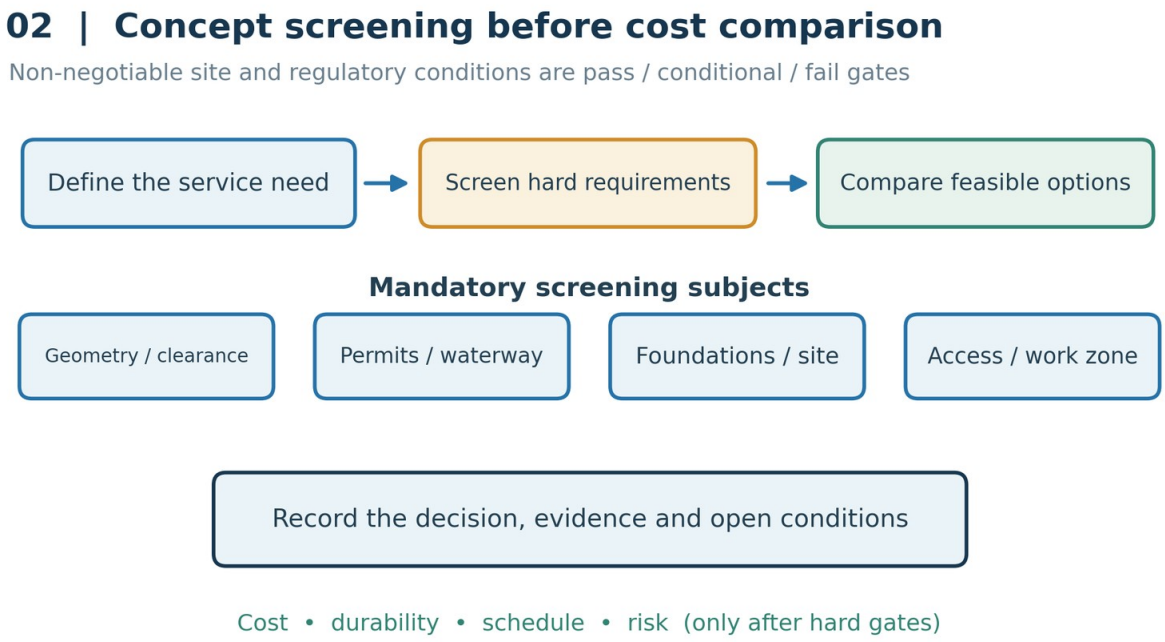


Figure 2. Screen mandatory project constraints before comparing cost, schedule and maintainability.

2.6 Worked example: alternative selection with hard gates

A county is comparing three options for a two-lane local roadway bridge. The existing structure has deteriorated joints and a history of temporary flood closure. Option 1 uses a new single span to avoid in-channel construction but requires a taller approach embankment. Option 2 uses a two-span arrangement with a pier in the channel, maintaining existing roadway grades but increasing the scope of hydraulic and scour work. Option 3 rehabilitates the existing bridge and retains the existing span arrangement. All are at concept stage. The project team cannot decide from a material-cost table because minimum hydraulic and operational criteria have not yet been established.

First screen the hard requirements: can each option satisfy essential access, owner-required width, traffic restrictions, right-of-way and documented permit constraints? A rehabilitation that leaves the functional deficiency unresolved is not equivalent to a replacement if the owner has established a nonnegotiable width requirement. A channel pier may be acceptable or not; that requires hydraulic evaluation and agency coordination, not assumption. A taller embankment may produce flooding or adjacent drainage consequences. Until these questions are resolved, each option is identified as “pass,” “fail,” or “conditional” with the condition written out.

Only then compare feasible alternatives by a consistent basis: construction and detour duration, environmental complexity, total construction cost, maintenance intensity, inspection access, service-life risk and residual uncertainty. Assume the concept team estimates capital costs of $4.1 million, $3.7 million and $2.8 million for Options 1, 2 and 3, respectively. These illustrative values are not bids or validated estimates. They cannot establish that Option 3 is cheapest over the owner’s study period

because future traffic disruptions and required rehabilitation depend on asset condition and functional life. A sensitivity test should ask whether a bridge closure or unexpected foundation work would reverse the ranking.

Suppose one in-channel pier raises major permit uncertainty for Option 2, while a geotechnical investigation suggests Option 1 may require ground improvement. The correct next step is not to hide these issues in an arbitrary average rating. The team should commission focused investigation, define the decision threshold and set an owner meeting to accept or reject the remaining uncertainty. A mature concept study gives decision-makers a range of outcomes and a reasoned recommendation conditioned on evidence.

This example also illustrates the role of an engineer with substantial transportation experience: cross-disciplinary awareness matters because the best structural answer is not necessarily the best corridor answer. Bridge selection is inseparable from road profile, drainage, traffic control, construction access, environmental authorization and long-term operations. The course does not claim a specific professional designed the example; its lessons emphasize real transportation interfaces and decision quality.

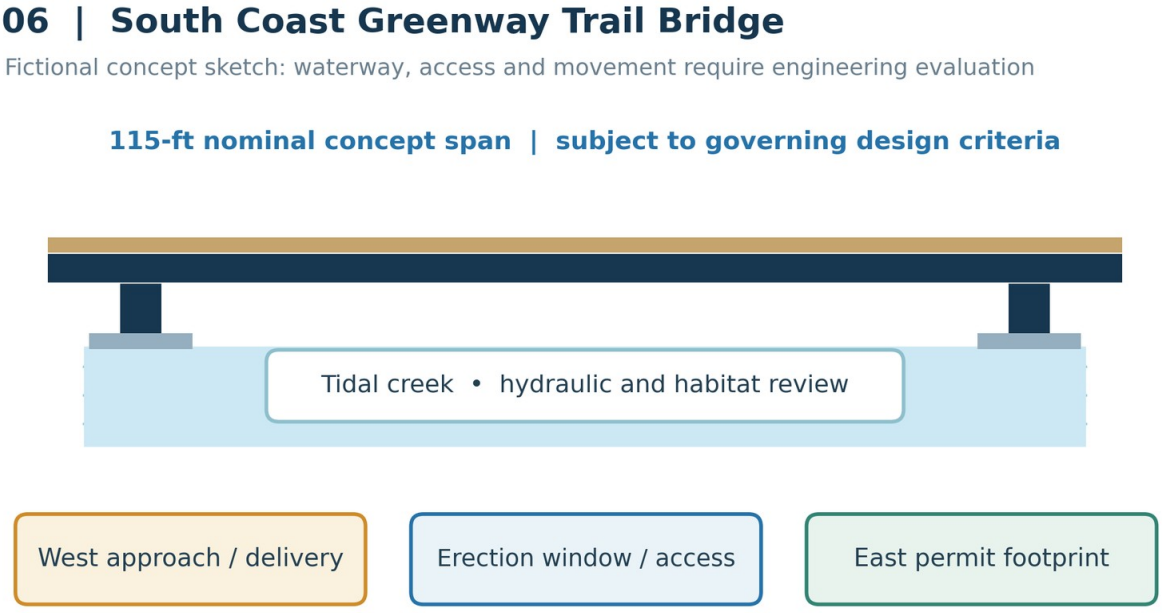


Figure 3. Fictional South Coast Greenway Trail Bridge concept constraints and access zones.

2.7 Project development record: what to preserve

The decision record should contain a drawing-based alternative definition, survey date and control, geotechnical scope and limitations, hydraulic models and events studied, preliminary environmental and permit correspondence, utility owner contacts, applicable roadway and bridge criteria, traffic detour plan, estimates with assumptions, and an open-issues register. A cover page saying “coordination complete” is inadequate if the underlying permissions and interfaces remain

unresolved. Future reviewers must be able to reconstruct why the selected option was defensible at the time.

When the project passes from planning to design, hold a structured transfer meeting. List the decisions that may no longer be changed without owner approval; list data still expected; and distinguish a conceptual estimate from a final bid quantity. This prevents a concept sketch from being treated as a precision survey or a preliminary bearing orientation from becoming a construction instruction.

Module 2 | Applied engineering workshop

Alternatives-screening exercise (25 minutes). The hypothetical South Coast Greenway Trail crossing spans a 95-ft tidal creek reach. Three possible schemes are (A) one 115-ft prefabricated steel pedestrian span with abutments outside the ordinary channel, (B) two shorter steel spans with one in-channel pier, and (C) one cast-in-place concrete span requiring long-duration falsework within an environmentally constrained construction zone. This is a comparison problem, not a declaration that any alternative meets design code. Use the provided decision matrix to write a gate/pass/uncertain entry for waterway permit footprint, ground investigations, delivery route and erection feasibility, trail closure duration, corrosion/service-life approach and maintenance access. Select a provisional preferred concept, identify two investigations that could change it, and compose a six-sentence owner briefing. Discuss the danger of assigning a numerical score to an unverified permit assumption.

Five-minute consolidation

Review your alternative matrix for any criterion that must be satisfied before comparing cost. Identify the study, permit decision or owner approval that would close your most important conditional item.

Technical reference pointers

Related source entries: [1], [5], [9].

MODULE 3 | Design coordination, constructability and detailing

75 minutes • Reading/diagram analysis 35 min • Applied worksheet 35 min • Consolidation 5 min

The highest-value design reviews follow the interfaces that can make an otherwise adequate structure unbuildable or unmaintainable.

3.1 Governing design basis and document hierarchy

AASHTO LRFD Bridge Design Specifications, 10th Edition (2024) with September 2025 errata is a major current bridge-design reference; adoption and applicable edition depend on the owner, jurisdiction, contract and relevant federal requirements. The project design basis should identify its governing edition, project-specific amendments, loading and performance criteria, owner standards, materials, site data, analysis assumptions and exception approvals. Avoid mixing a new design clause with an older commentary or agency detail without documenting the reconciliation. An engineering review is not a code lookup performed in isolation.

Keep a clear distinction among technical design standards, construction specifications, fabrication specifications and best-practice guides. For steel bridge fabrication, the current AASHTO LRFD Steel

Bridge Fabrication Specifications, 1st Edition (2023) with 2024 and 2025 interim revisions supersedes the archived AASHTO/NSBA S2.1-2018 guide. The older guide must not be presented as the active contract standard. Construction should be coordinated with the AASHTO LRFD Bridge Construction Specifications, 4th Edition, incorporating its applicable interim revisions through 2025 when adopted by the project.

A March 17, 2026 FHWA information memorandum approves optional use of identified newer design and construction standards for relevant federal-aid work; it does not make those editions mandatory, and the formally incorporated requirements continue to apply unless changed by governing authority. The contract hierarchy matters during shop drawing review. An approved shop drawing does not automatically authorize a departure from design requirements, and the meaning of review stamps is governed by contract language. A controlled variance should identify the specific requirement, proposed change, effect on load path/durability/fabrication, authorized decision and revised contract record. The reviewer should flag risk without accepting engineering responsibility outside the assigned scope.

3.2 Align geometry, foundation and structural assumptions

The structural model assumes support points, elevations, bearing geometry, fixity, geometry and material properties. Survey and geotechnical teams provide data with uncertainty, not an unlimited guarantee about each location. A grade change can alter minimum depth, clearance, approach geometry and pier height. A foundation change can modify stiffness, settlement, constructability and substructure design. Align the current general plan, profile, foundation schedule and analysis model before issuing final plans.

Skew and curvature affect load distribution, cross-frame arrangement, reactions, girder detailing and erection behavior. A skewed bridge seat should be evaluated for physical bearing access and movement along intended directions. Complex steel geometry may require more sophisticated analysis than a simple line-girder model. In concept review, record whether global analysis, staged analysis, refined deck distribution, fatigue or stability calculations are required rather than forcing a rough screening equation into a final design role.

Check foundation drawings against known utilities, adjacent properties, erosion protection, dewatering and allowable construction vibration. An abutment that fits geometrically may not be constructible if the excavation undermines a nearby active roadway. Similarly, a pile cap over an existing buried utility requires an engineered resolution, not an on-site relocation based on a clash view.

3.3 Steel girder layout and fabrication logic

Steel plate girder bridges often have economies linked to plate availability, splice positions, girder depth uniformity, cross-frame geometry, welding access and transport limits. The AASHTO/NSBA G12.1-2020 guidance connects design for constructability with practical fabrication and erection. A technically valid plate transition can still be costly if it multiplies shop welds or requires unusual handling. Designers should discuss feasible plate thickness transitions, curved-component tolerances and shipping envelopes with fabricators when major geometry is still adjustable.

Shop details must express member orientation, piece marks, fit, dimensions, weld and bolt requirements, coating interfaces and field splice locations. Review whether detailers and inspectors can reach the required welds, bolts and attachments. Fatigue-sensitive details deserve particular attention where nominally minor attachment geometry changes the stress range or inspection access. Avoid specifying undocumented repairs or field welding alterations merely to make a piece fit. An accepted fabrication issue requires documented engineering disposition.

Steel erection is a changing system. An individual unbraced girder may behave differently from the final composite bridge, and construction stability can govern lift and temporary-bracing design. Record responsibility for erection engineering, temporary works, sequence, crane positioning, available work windows and weather limits. The structural designer's final-condition drawings are not a complete lift plan or erection stability analysis.

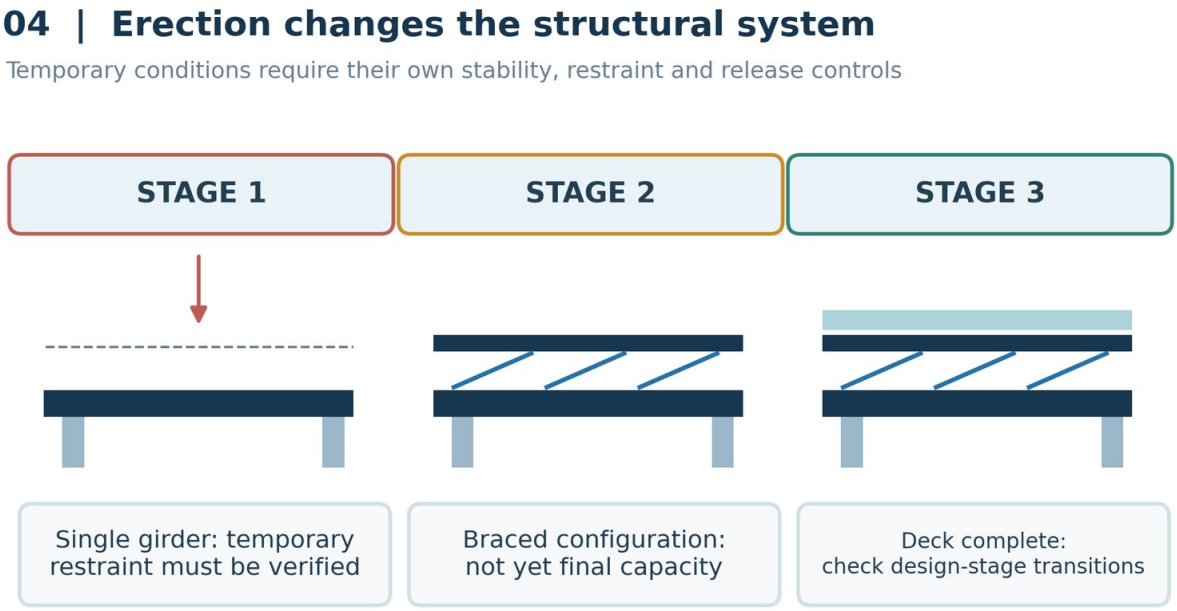


Figure 4. Temporary erection configurations require separate stability and restraint consideration.

3.4 Concrete systems and service-life details

For concrete bridge decks and substructures, check reinforcement constructability, congestion at diaphragms or joints, cover requirements, exposure, curing access, concrete placement sequence, prestressing details and inspection access. A reinforcement arrangement that is buildable on paper may not allow proper consolidation or accommodate form ties and embedded elements. Constructability review should catch such conflicts before concrete is placed. The governing concrete design and construction requirements must be derived from the project's adopted specifications, not generic building-code assumptions.

Water management is a first-order durability topic. Deck drainage, slope, scuppers, downspouts, joints, cracked concrete, waterproofing and chloride exposure affect how water reaches reinforcing steel, bearings, beam ends and caps. Repairing a deteriorated beam end without correcting the leaking deck

joint can allow the same cause to recur. Detailers should show a continuous path for drainage away from sensitive structural elements and an inspection/cleaning strategy for that path.

At precast bridge elements, evaluate lifting inserts, shipping and storage supports, closure pours, connections, tolerances and temporary load states. At post-tensioned elements, grout, duct detailing and protection demand qualified specialist coordination. Even a bridge that appears repetitive across spans can have unique geometric or erection constraints at one support that justify a separate detail or sequencing note.

3.5 Bearings, joints, drainage and maintainability

A bearing's purpose is not simply to separate a beam from a pier. It transfers specified actions while allowing or restraining particular movements and rotations. The design basis should explain fixed and expansion locations and recognize how thermal movement, creep, shrinkage and substructure flexibility interact. Evaluate access for installation, inspection, cleaning and replacement. Jacking provisions, if required, must be engineered, documented and constructible in the finished bridge.

Expansion joints require coordination among structural movement, ride quality, drainage, deck construction and anticipated replacement. Where a joint is omitted, the designer must ensure movements are accommodated elsewhere by the adopted concept and details. Water should not discharge directly over critical bearings or unprotected steel. At a multi-unit bridge, check that each joint and bearing line matches the analytical model and design movement directions.

A maintainability review asks whether a future crew can see the defect, gain safe access, close the relevant lane if necessary and replace an item without disproportionate structural intervention. A detail that reduces first cost while creating a permanent blind spot or requiring major demolition for routine service should be questioned while design alternatives remain available.

3.6 Constructability and interdisciplinary clash management

Build a clash matrix across interfaces: roadway–deck grades, drainage–bearings, utility–cross-frames, geotechnical–foundation, traffic staging–erection, temporary works–environmental windows, fabrication–shipping, accessibility–approach geometry and owner maintenance–joint detailing. Classify each issue as geometry, loading, approval, constructability, durability or ownership; some issues will span several categories. The classification suggests the parties who must participate and the evidence needed to close the issue.

A useful review meeting starts with the drawing or model view, identifies the conflicting requirements, describes the consequence and records one owner with a due date. The engineer of record should evaluate material design changes; the contractor or specialty engineer should evaluate means and methods within their contractual obligations. A redlined coordination model is a discovery device, not automatically the issued contract record. Resolution is complete only after affected documents, approvals and downstream users have been reconciled.

Formal constructability review is most effective before irreversible procurement. Shifting a field splice after shop fabrication has begun may change material quantities, shipping and lifting assumptions, corrosion protection and schedule. Issuing detailed review comments early is more valuable than simply increasing the number of comment rounds after the design has been frozen.

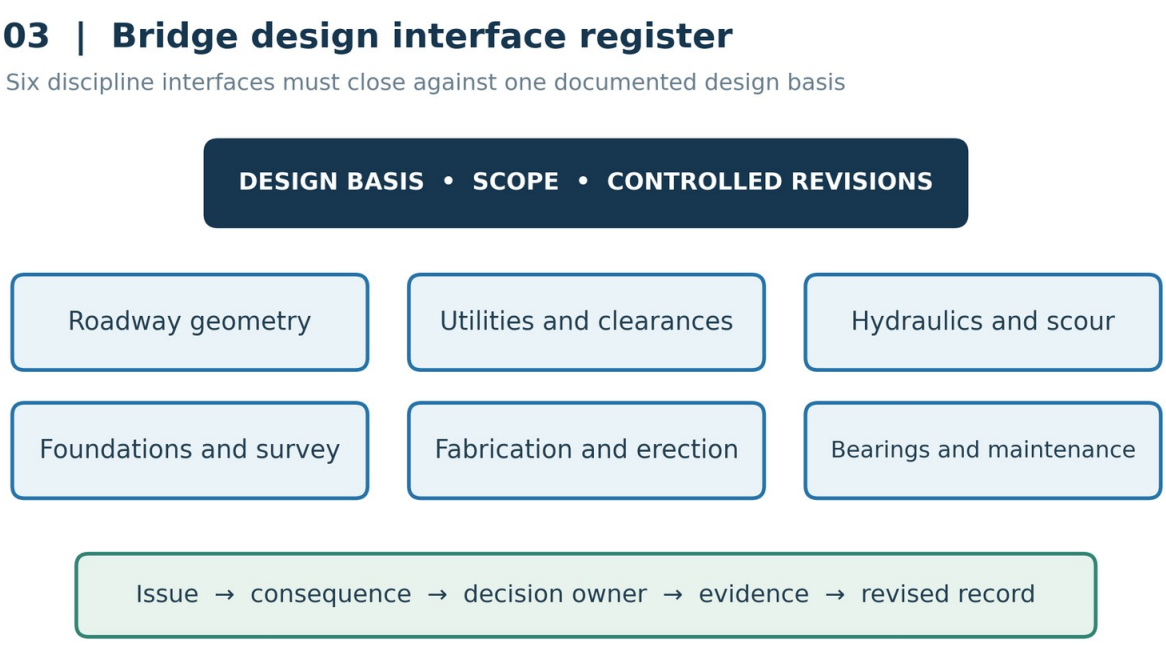


Figure 5. Bridge design interface register connects six disciplines to one coordinated design basis.

3.7 Independent check and change traceability

Engineering checks should include verification of design assumptions, load path, analysis method appropriateness, component design, detail consistency, specifications, quantities and interdisciplinary interfaces. The level of independence and checking is defined by the owner and organization's QA program. A computer output is evidence of a calculation, not evidence that the right model, support conditions or load cases were chosen. Ask what physical behavior the model is intended to represent and what observations would invalidate the assumptions.

When a late change occurs, trace its effect across calculations, drawings, schedules, specifications and construction documents. A pier movement could affect span arrangement, girder reactions, utility crossings, hydraulic blockage, geotechnical design and erection sequence. One revised plan sheet is insufficient if the coordinated design baseline remains inconsistent. The issue log should include the authorization path, updated revision identities and a closure check by the affected disciplines.

This approach creates a practical audit trail. The project can show that a major risk was recognized, evaluated by qualified personnel, incorporated into the governing documents and communicated. That does not guarantee absence of error; it makes the design review transparent and reviewable.

3.8 Worked example: a steel bridge interface issue through four design stages

At preliminary design, a 210-ft two-span steel girder bridge crosses an active rail corridor at a skew. The framing plan specifies a field splice near the midpoint of the longer span. A utilities consultant proposes a large duct bank at the eastern abutment. Construction access includes a narrow corridor on one side of the bridge. The team's preliminary review should ask whether the splice can be reached safely, whether shipping length is feasible and whether erection can maintain clearance to the rail owner's operating envelope. The issue is larger than a dimensional clash.

At 30% design, the design manager requests a confirmation list: girder geometry, stage-specific stability concept, field-splice location, shop-weld vs field-bolt division, temporary bearing conditions, rail approval path and utility relocation windows. Some are structural design tasks; others belong to construction planning or third-party approval. The team should not mark an issue “closed” because it appears on a drawing. Closure requires evidence from each responsible party and an accepted revision to the design basis when needed.

At 60% design, the fabricator reports that one girder segment exceeds the available shipping route turning envelope. The team compares shifting the splice, segmenting a member, revising girder selection or changing access. Each can change structural analysis, field connections, cost, coating and erection. A decision record identifies who is authorized to choose; the design professional must accept changes to the structural system, while the contractor plans the means and methods under the contract. Transportation permits and railroad approvals may require separate action. Cost pressure cannot transfer unassigned engineering responsibility to a shop detailer.

At 90% design, a model-check report finds an ambiguous bearing orientation at the skewed abutment. The plan shows a guided axis parallel to the girder, while the detail references roadway alignment. These may differ materially for a skewed bridge. The engineer reviews the movement analysis and issues a corrected bearing schedule, plans and notes. The team verifies that the fabrication submittals, structural model and erection plans reference the corrected revision. A single corrected image in the BIM model would not establish a controlled design change.

After construction starts, the same review log can be used to manage field RFIs. Each answer should identify its technical basis, affected documents, authorized disposition, contractor sequence implications and required verification. If an answer changes a load path or approval condition, it triggers the corresponding design and owner process. This prevents a late fit-up response from silently becoming an unreviewed redesign.

3.9 A concise constructability-check record

A practical issue entry contains eight fields: ID; element and station; controlling drawing and revision; condition or conflict; potential consequence; responsible decision-maker; required evidence or approval; and closure status with verification reference. For a cross-frame versus utility conflict, “Provide clearance” is not enough. The entry should state the measured or modeled interference, where the utility can be moved, whether changing the frame affects the design model, who accepts the relocation, and which drawings and submittals are revised.

Effective reviewers avoid comment inflation. If five comments have the same root cause—a wrong alignment revision—they should identify the common root and enumerate affected elements. Conversely, a general note to “coordinate utilities” is too vague to verify. A good comment has a physical referent, a real consequence and a clear acceptance test. One well-resolved interface can prevent more rework than a long list of formatting comments.

Module 3 | Applied engineering workshop

Interdisciplinary constructability workshop (35 minutes). A proposed curved two-span steel roadway bridge has a 14-degree skew at the east abutment, a 2.8-ft-deep cross-frame envelope at a

utility crossing, a 1.9-ft nominal utility clearance shown in an older model, a proposed field splice above a sensitive wetland access route, and bearings whose long-axis orientation differs between plan and section. The values are fictional coordination inputs, not acceptance criteria. Identify six conflicts or missing confirmations. For each, record affected sheets, probable design or staging consequence, engineering decision owner, required new information and a hold/release criterion. Next, compute the screening movement for a hypothetical 180-ft unrestrained steel length with $\alpha=6.5\times10^{-6}/°F$ and $\Delta T=75°F$ (result about 1.05 in), then explain four reasons the project movement schedule may differ. Prepare a formal resolution record for the bearing-axis discrepancy. **Required deliverable:** an issue register and a one-page statement of what cannot be accepted by shop-drawing review alone.

Five-minute consolidation

Check whether your interface register identifies the controlling drawing revision, the construction-stage consequence and the engineering authorization. Make sure the bearing-axis conflict is resolved in every affected record.

Technical reference pointers

Related source entries: [1], [2], [3], [4], [10].

MODULE 4 | Construction, fabrication and quality assurance

75 minutes • Reading/diagram analysis 35 min • Applied worksheet 35 min • Consolidation 5 min

Quality is the documented connection between approved requirements, field evidence and authorized decisions.

4.1 Establish construction responsibilities

Construction quality management must distinguish quality control (QC), which is performed by the organization producing the work to ensure conformance, from quality assurance (QA), which provides the owner or its representative with evidence that the required process and acceptance controls are effective. Contract-specific responsibilities vary. The engineer of record controls design interpretations and authorized engineering modifications; the contractor controls execution and generally its means and methods, subject to the contract. Specialty engineers may design falsework, erection bracing or delegated components. No general course can replace project contract assignments.

Before mobilization, link the approved plans, specifications, approved submittals, inspection/test plan, material certifications, personnel qualifications and change-control process. A hold point is meaningful only when the parties know what must be observed, who may release it, what record proves acceptance and what occurs if the point fails. An inspection witness is not automatically an acceptance authority.

Preconstruction meetings should cover temporary access, emergency procedures, weather response, working over water, utility protection, traffic control, environmental permits, construction survey, material storage and the path for unexpected conditions. Schedule pressure is a known source of undocumented field decisions. A concise escalation procedure gives crews a practical alternative to improvising modifications under deadline.

4.2 Submittals, fabrication and material traceability

Fabrication quality begins with traceability of material identification, certified test reports where required, heat or lot identification, approved welding procedures, welder qualification, bolting systems, coating and dimensional controls. The governing fabrication specification and project requirements determine the exact evidence and acceptance limits. Not every shop drawing is a design calculation and not every manufacturer's certificate is proof of proper installation. The QA plan should show where incoming material is checked and how records follow the component to the field.

Review steel fabrication for plate cuts and holes, fit-up, weld access, distortion, camber, sweep, tolerances and field splice readiness. Quality failures can arise from a detail that is difficult to fabricate as well as from execution. A weld discontinuity observed during testing should be classified against the applicable acceptance standard by qualified personnel; it is neither automatically acceptable nor automatically evidence of total structural failure. Document the disposition and retesting requirement if applicable.

The current AASHTO LRFD Steel Bridge Fabrication Specifications with 2024 and 2025 interim revisions should be used where adopted rather than the archived S2.1-2018 document. The project specification remains controlling for required tests, inspectors, acceptance criteria and remedies. The 2025 AASHTO/AWS D1.5M/D1.5 bridge welding-code edition is also identified in FHWA's March 2026 memorandum; the project-adopted welding requirements remain the acceptance basis. Independent audits may verify compliance, but production personnel remain responsible for their assigned QC.

4.3 Erection and temporary-condition stability

An erection sequence changes how the structure carries its own weight. Before the deck or permanent diaphragms are in place, a girder line may need temporary restraint to prevent lateral instability, rotation or unintended displacement. Staging, support settlement, lift configuration and weather exposure can govern construction-stage forces. Work over water, a highway or rail corridor adds access constraints and third-party safety obligations. The erection engineer should establish sequence, brace requirements, temporary support capacities, survey tolerances and stop-work triggers.

Field splice fit-up depends on temperature, support conditions, girder geometry and sequence. Forcing a connection into alignment without an approved evaluation can transfer unintended forces or damage elements. If a girder arrives outside documented tolerances, verify survey controls and compare the measured discrepancy with accepted limits. The project must then obtain engineering disposition before making physical adjustments that affect the design. Record any approved rework and subsequent verification.

Temporary works are not a casual means-and-methods footnote when their failure could destabilize the bridge. The contract and applicable AASHTO construction requirements define responsibility. The release checklist should include approved temporary works engineering, inspection of installed bracing and supports, lifting plan, exclusion zones, communications and the sequence for removing temporary restraint.

4.4 Concrete placement and post-tensioning interfaces

Before placing a bridge deck or cap, confirm forms and falsework, reinforcement and cover, embedded items, deck elevations, pour sequence, access for consolidation, environmental controls, laboratory testing arrangements and curing materials. Hold points should occur while the condition is visible. A hidden reinforcing conflict is expensive to correct after concrete is placed. A useful pre-pour checklist names both inspected features and the requirement used to accept them.

Concrete quality depends on the approved mix and production controls, delivery and placement conditions, consolidation, finishing, curing and test evidence. A cylinder result is one part of acceptance; the specification governs sampling, maturity, strength and related testing. Do not substitute one generic temperature or strength value across projects. When a result falls outside the requirement, the construction team should protect the work and obtain an authorized engineering evaluation rather than delete the record or assume all material must be removed.

For prestressed or post-tensioned systems, stressing sequence, equipment calibration, strand/duct condition, anchorage and grouting operations require specialist control. Inaccessible ducts or poorly documented grout operations can create a durability risk that is difficult to evaluate later. The construction quality file should retain procedures, measurements, nonconformance actions and acceptance evidence in a form the owner can use throughout the service life.

4.5 Geometric, bearing and drainage verification

Survey controls bridge geometry: line and grade, bearing elevations, girder seat positions, deck elevations and approach transitions. Survey results should be compared with acceptable tolerances at the proper construction stage. A camber measurement before deck placement is not necessarily the same as final profile. Where temperature or time effects are significant, record the conditions at measurement and compare with the designer’s approved interpretation.

Bearing installation is a critical coordination point. Check type, location, orientation, seating, contact, temporary restraints and approved movement settings. A reversed guide or incorrect preset may not be obvious once the deck is placed. Similarly, deck outlets and drain leaders must terminate where the detail intends, not onto the steel beam ends or bearing seats. Photographs should be tied to location, date, issue and governing drawing rather than kept as a disconnected camera archive.

The turnover record should identify baseline movement, surveyed positions, accessible inspection points, joint details, drainage routes and maintenance instructions. The future bridge inspection team benefits from knowing not just what was built, but which field changes were evaluated and accepted. A complete record reduces uncertainty when the bridge begins to show distress.

4.6 Nonconformance and engineering disposition

A nonconformance occurs when a verified requirement is not met. The response is to secure the work as needed, describe the deviation objectively, identify affected scope, preserve relevant evidence, assign a decision authority and obtain an accepted disposition before irreversible next steps. Common dispositions may include approved rework, repair, use-as-is acceptance with an engineering basis, or removal and replacement. Which options are allowed depends on the contract, safety and design requirements.

Distinguish observation from inference. “A 9-mm gap was measured at field splice S-4 against drawing XYZ revision 5” is a useful observation. “The contractor built an unsafe bridge” is an unsupported conclusion without engineering analysis. A documented technical review considers structural consequences, fabrication tolerance, fatigue, durability, appearance, contract conditions and related elements. If work can safely continue in unaffected areas, define that boundary precisely.

For every corrective action, verify execution and close the loop with updated records. A resolved discrepancy that is not reflected in as-built information can reappear as an inspection mystery or future repair mistake. Effective quality systems also investigate recurrence: was the root cause a wrong drawing revision, inadequate survey, fabrication error, unbuildable detail or missing responsibility? A corrective action that merely repairs the symptom may leave the system vulnerable.

07 | Construction hold points

Observe the condition before concealment; release is defined by the contract authority

RELEASE STAGE	EVIDENCE	IF MISSED
Foundation setup	Survey + ground record	Unexpected support
Girder erection	Bracing + lift control	Stage instability
Deck pre-pour	Rebar, embeds, forms	Concealed conflict
Joint / bearing	Orientation + movement	Leakage / restraint
Handover	As-built + QA records	Future uncertainty

Close each hold point with a dated record and the required release.

Figure 6. Construction release stages and the consequence of missing required verification.

4.7 Documentation and turnover for the owner

Closeout is the endpoint of a controlled evidence chain. The owner should receive structural calculations and design changes as required; approved plans; testing and inspection records; material certifications; fabrication and erection records; post-tensioning and concrete documentation; accepted nonconformances; bearing and joint setting data; as-built survey; environmental closeout; and maintenance access instructions. File names and revision labels should make this package searchable without specialist recollection.

Create a location-based index of future maintenance items. Bearings, expansion joints, drains, coatings, cathodic protection or instrumentation need identification, inspection access and manufacturer data when relevant. A construction photograph should be traceable to a component and the issue it addresses. The turnover package is part of the asset's management system, not just evidence of a successful final invoice.

An effective handover meeting identifies restrictions, open monitoring requirements, initial inspection expectations and warranties. A bridge can be accepted for service while some administrative closeout remains, but any remaining technical issue needs explicit risk ownership and a documented path to closure. Acceptance does not erase the need to manage an unresolved condition.

4.8 Worked example: investigate before authorizing repair

During erection of a steel plate girder bridge, a survey crew reports that a bearing plate is offset by 0.6 in relative to the erection drawing. The erection foreman says the girder can be “pulled” into alignment with a temporary chain hoist. The engineer must first determine what reference is being compared: is the plate offset from the design centerline, from the current as-erected girder position, or from an outdated field layout? What was the temperature and support stage when surveyed? Is the apparent discrepancy outside the project tolerance? The measurement is a condition, not yet a diagnosis.

The appropriate immediate action is to protect the work and prevent irreversible adjustment until the responsible technical parties evaluate the difference. Confirm control points, survey method, current drawing revisions, support condition and intended movement orientation. Then determine whether additional displacement would introduce stress, compromise bolt fit or alter bearing restraint. If the structural designer accepts a corrective action, the contractor or specialty engineer develops a safe sequence as required. The field change is recorded with revised documents, installation measurements and final acceptance evidence.

A separate example occurs during deck preparation. An embedded conduit crosses a reinforcement mat at a location where minimum cover, spacing or consolidation may be impaired. The crew cannot decide to cut bars because the new routing “looks cleaner.” Stop the affected placement, document the interference and obtain an authorized design resolution. The revised detail may require conduit relocation, reinforcement changes with calculation support, changes in placement sequence or other engineered measures. After implementation, reinspect the concealed elements before placing concrete.

These examples have the same quality-control logic but different engineering questions. The bearing issue concerns load transfer, restraint and temporary force effects. The conduit issue concerns reinforcement geometry, durability and placement quality. A generic “repair as directed” instruction would be insufficient because it does not identify technical acceptance, responsible engineering or future records. Good quality management moves from observation to assessment, disposition, rework verification and document closure.

The construction QA file should also distinguish initial observation from accepted nonconformance. If the survey is found to use the wrong reference coordinate, the first report remains as a traceable observation while the finding explains why no physical correction was required. This protects technical integrity and allows root-cause learning in the project’s surveying process.

4.9 Handover package as an engineering resource

Imagine a future maintenance engineer investigating a stuck bearing. Three records would be particularly useful: the approved movement schedule and original bearing preset, the as-built survey

with conditions at installation, and the repair history of nearby joints and drainage. Material test reports alone will not explain the observed restraint. The same logic applies to concrete: embedded details, placement records, and locations of accepted repairs reduce uncertainty about later cracking.

Organize records by bridge asset, element ID and location. Include metadata for date, drawing revision, test type, responsible organization, disposition and linkage to photograph or model. Retain the original nonconformance and final closure evidence; do not overwrite the former with a clean "as-built" sheet alone. A turnover package designed for future investigations is one of the most cost-effective durability measures available during construction.

Module 4 | Applied engineering workshop

Construction hold-point workshop (35 minutes). At the fictional East Marsh Highway Bridge, the following sequence is scheduled: shop release, steel girder delivery, support survey, first-girder erection, cross-frame completion, deck pre-pour, joint installation and turnover. During the first-girder lift, a support appears 0.7 in above the assumed elevation in the erection plan; later, an embedded conduit conflicts with the deck reinforcement at the haunch. The measurements are hypothetical observations, not statements that tolerance is exceeded. Create an eight-row inspection/test plan specifying the controlling document, responsible QC party, owner QA/witness function, evidence, release authority and stop-work condition. Write two nonconformance reports describing observations without declaring structural adequacy. Identify which work is safe to continue only after authorization, and list the evidence needed for documented closeout.

Five-minute consolidation

Review the release matrix for concealed work, evidence requirements and an identified authority. Rewrite any nonconformance conclusion that goes beyond the observed measurements and approved engineering evaluation.

Technical reference pointers

Related source entries: [2], [3], [6], [10].

MODULE 5 | Condition assessment and deterioration mechanisms

60 minutes • Reading/diagram analysis 25 min • Applied worksheet 30 min • Consolidation 5 min

An observed defect is a clue. Its severity, extent, mechanism and consequence require evidence and qualified engineering judgment.

5.1 Inspection information and its limits

Bridge inspections provide condition evidence, not an automatic determination of remaining load-carrying capacity. Under the National Bridge Inspection Standards (23 CFR 650 Subpart C), relevant public bridges are managed under defined programs with personnel qualifications, inspection procedures and reporting obligations. The FHWA Bridge Inspector's Reference Manual and state

program manuals support inspection practice. Completing this course does not qualify a person as an NBIS team leader or replace FHWA-approved comprehensive bridge inspection training.

A condition rating is a useful trend indicator but cannot describe every local risk. A bridge with generally fair components may have a critical local defect requiring immediate attention, while a visually poor nonstructural feature may not govern capacity. Inspectors should document exact element, location, dimensions or extent, observed change, cause hypotheses, photographs and accessible supporting data. When the consequence is uncertain, elevate to appropriate specialists rather than convert a rating into an unsupported design result.

Condition information must be interpreted with the record of past repairs, exposure, traffic loads, scour, fatigue details, and inspection access. A bridge may appear stable because a poorly accessible area has not been seen recently; missing observations are not equivalent to positive evidence. The asset manager should mark inspection limitations and decide whether access equipment, non-destructive evaluation or targeted analysis is needed.

5.2 Corrosion and concrete deterioration

Steel corrosion requires an electrolyte and can be accelerated by chloride exposure, trapped moisture, crevices and defective coating. Localized section loss at a girder end or connection may be more consequential than an extensive surface discoloration in a less stressed area. Coating failure should be documented with substrate condition, location of water entry, drainage source and access constraints. A repair approach must address both remaining material and the condition that allowed deterioration to occur.

In reinforced concrete, water and chlorides can destabilize the protective environment around steel, creating corrosion products that expand and cause cracking, delamination and spalling. Other mechanisms include freeze–thaw deterioration, alkali-silica reaction, abrasion, chemical attack and construction defects; symptoms overlap, so diagnosis matters. A rust stain alone does not establish corrosion depth, and one crack width measurement does not establish safety. Map pattern, orientation, moisture conditions, exposure and change over time.

Testing options include cover survey, sounding, half-cell potential, chloride profiles, resistivity, petrography, cores or targeted ultrasonic methods as justified. Each has limitations. For example, a corrosion-potential measurement indicates risk of activity under certain assumptions, not a direct measured bar-loss percentage. Diagnostic testing is selected against an explicit decision such as whether a localized patch is adequate or a broader protection system is warranted.

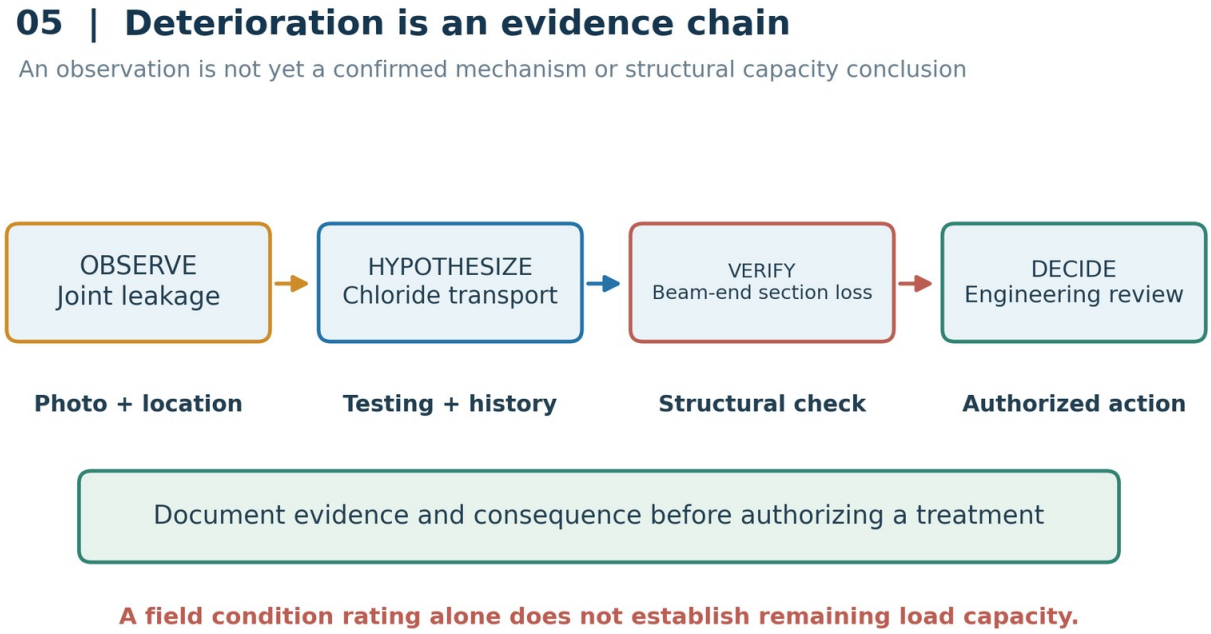


Figure 7. Observed deterioration must be interpreted through evidence, mechanism and consequence.

5.3 Fatigue, fracture and connection distress

Repeated stress ranges can initiate or propagate cracks at susceptible details even when nominal maximum forces are below static strength limits. Inspectors and designers need a map of detail categories, weld geometry, secondary stresses, connection restraint and history of known cracking. A crack visible at a welded attachment may be the symptom of a mechanism that remains active after surface grinding. Qualified evaluation determines whether immediate restrictions, more detailed testing, repair, retrofit or monitoring are appropriate.

Fracture consequence depends on structural system, load-path redundancy, detail behavior, material toughness, inspection interval and existing damage. Do not infer “fracture critical” or another formal classification merely from the appearance of a large steel member. Federal inspection terminology and requirements have evolved; the applicable owner program and governing standards should be consulted. A suspected crack in a potentially critical element requires a prompt, controlled escalation.

Connection problems can present as movement, bolt distress, unexpected deformation, loose or damaged components or coating cracking at interfaces. Document the as-found condition before adjustment. The engineer must establish whether the issue is loss of connection capacity, serviceability, corrosion, fit-up or a secondary stress path. Routine maintenance should not erase evidence required to understand an active mechanism.

5.4 Bearings, joints, drainage and scour

Bearings may bind, rotate unexpectedly, accumulate debris or suffer component deterioration. A joint can leak or lose movement capability, directing chlorides to beam ends and seats. These defects often operate as a chain: failed drainage causes local moisture; moisture accelerates corrosion; corrosion

can impede movement and damage adjacent concrete; movement restraint may produce new distress. Record relationships rather than treating each defect in isolation.

Scour removes material supporting foundations, and it may occur below the water surface where casual visual inspection cannot quantify it. The FHWA HEC-18 framework and the bridge owner's scour program are the correct context for evaluating foundation vulnerability. A single low-flow observation cannot establish sufficient foundation embedment during major floods. Evidence sources include historical hydraulic and scour analysis, channel surveys, underwater inspections, observed bed change and flood/debris history.

When a significant scour concern arises, the next action may involve immediate response, more measurement, structural and geotechnical analysis, countermeasure selection or operational restrictions. This is an owner-authorized engineering decision. The checklist should show observed triggers and an escalation contact so findings are handled within the relevant program, not buried in a periodic report.

5.5 Diagnostic triage and action thresholds

Create a triage table that separates observations into "document and monitor," "investigate promptly," and "urgent operational escalation," with classification based on project-specific engineering judgment. The table should name an authority rather than prescribe universal defect dimensions. Unexpected large deformation, rapidly progressing crack growth, loss of support, suspected major impact damage or evidence of active foundation instability warrant prompt escalation; ordinary localized coating breakdown may be scheduled for condition-based maintenance after assessment.

When inspection limitations prevent confident diagnosis, classify the uncertainty explicitly. The risk of making the wrong decision depends not only on likelihood but on consequence, access and speed of deterioration. A targeted investigation can be economical if it prevents major unnecessary rehabilitation or catches hidden loss. Conversely, testing without a defined decision question can produce data with no action pathway.

Close a finding with a technical disposition: what was observed, probable mechanism, further information, immediate operations decision, selected intervention or monitoring, responsible engineer, due date and updated asset record. If a full capacity determination is needed, it belongs in a load-rating or structural-evaluation process by qualified personnel using applicable standards, not in a visual checklist alone.

5.6 Worked example: build a diagnostic sequence rather than ordering every test

A highway bridge has repeated wet staining at the beam ends. One girder end shows section-loss concern, and a nearby concrete seat has cracking and spalling. An ineffective initial response would be to prescribe repainting and patch repair without confirming the source and extent of damage. A better response starts with an observed-condition map: locate all drains, joints, coatings, drip paths, corrosion sites, bearing interfaces and concrete damage. Compare records from prior inspections to distinguish active progression from old stable deterioration.

Next, describe three competing hypotheses. Hypothesis A: a failed deck joint is admitting runoff and deicing salts onto the girder end and seat. Hypothesis B: the downspout is blocked and discharging

water against the same area. Hypothesis C: water is accumulating from a separate local drainage defect. Tests and inspections should differentiate hypotheses. A controlled water-path investigation, accessible close-up visual examination, thickness measurements and selective material testing may be justified; the exact method must suit the owner's inspection procedures and safety constraints.

The evaluation must separate three decisions. First, is immediate operational restriction or emergency action indicated? That requires qualified structural judgment using the known condition and uncertainty. Second, what mechanism is active and what additional data would change repair scope? Third, what repair strategy will control both source and consequence? A targeted joint/drainage repair plus engineered steel or concrete work may be appropriate; a full replacement may also be necessary if the underlying damage is greater than initially observed. The course cannot choose between these without actual evidence.

An inspection report should include exact locations, date, environmental conditions, evidence of progression, test scope and limitations. For potential section loss, "severe rust" is not a substitute for thickness or section measurements where safe and warranted. Where inaccessible areas may hide damage, say so explicitly. An owner who knows where evidence is missing can commission a meaningful investigation instead of treating a gap as proof of adequacy.

A follow-up protocol defines the event that triggers reassessment. For example, repeat inspection after a completed water-control repair can verify whether the area remains dry, while a structural component repair requires whatever acceptance inspections and monitoring the responsible engineer specifies. No universal monitoring interval or threshold should be imposed on all bridges because consequence, site exposure and design details differ.

5.7 After an extreme event: factual escalation

After a major flood, earthquake or vehicle impact, an inspection team may encounter access restrictions, displaced debris, scour concerns and evidence of damaged connections. The purpose of an initial report is to provide verified observations and identify unknowns, not automatically clear the bridge for service. The owner's established emergency plan and qualified personnel govern access, operational restrictions and subsequent assessment. Attempting an underwater inspection during unsafe conditions does not improve the decision.

The first communication identifies the asset, event, known operational status, observed damage, inaccessible regions, immediate measures taken and who will make the next technical decision. As better evidence arrives, update the record rather than delete the initial report. This supports both public safety and forensic clarity.

Module 5 | Applied engineering workshop

Deterioration triage (30 minutes). At the same hypothetical creek crossing, an inspector records (1) deck joint leakage over the west girder end, (2) a 25% local coating loss estimated visually, (3) a suspected hairline crack at a welded attachment whose depth is unknown, (4) recent channel-bed change adjacent to a foundation, and (5) a blocked downspout directing water toward a bearing. No structural capacity values are supplied. For each, list the observable evidence, possible mechanism, missing verification, escalation tier and the appropriately qualified decision-maker. Draw a cause

chain linking joint leakage to at least two secondary defects. Identify one observation that must not be resolved using an arbitrary crack-width threshold, and one that requires waterway expertise. Write an owner notification that clearly distinguishes known facts from hypotheses.

Five-minute consolidation

Separate each field observation from a hypothesized deterioration mechanism and from a capacity judgment. Verify that every urgent or uncertain finding has a documented escalation path and decision owner.

Technical reference pointers

Related source entries: [5], [6], [7], [8], [9].

MODULE 6 | Preservation strategy and lifecycle decisions

45 minutes • Reading/diagram analysis 20 min • Applied worksheet 20 min • Consolidation 5 min

Preservation is a planned sequence of interventions that protects condition and function before damage forces costly choices.

6.1 Classify the action correctly

Routine or cyclical maintenance, condition-based maintenance, preservation, rehabilitation, major repair and replacement serve different purposes. Cleaning drains, washing joints, sealing appropriate surfaces and maintaining coatings can preserve otherwise sound assets when applied at the right time. Condition-based intervention responds to observed deterioration and its mechanisms. Rehabilitation restores or improves performance of a bridge with more significant deficiencies, often requiring structural evaluation and major construction. Replacement may be justified by condition, function, safety, economics or resilience, but it should not be the automatic response to a single unfavorable condition rating.

The FHWA Bridge Preservation Guide frames preservation as a systematic program. An action is not good preservation merely because it is less expensive than replacement. It must be appropriate for the asset condition, timing, environment and agency objectives. Patching concrete without diagnosing active reinforcement corrosion can create short-lived repairs. Painting steel without controlling recurring joint leakage can return the asset to the same deteriorating state. The intervention should address the cause as well as the damage.

Classify proposed actions by trigger and expected effect: what condition is being protected, what mechanism is interrupted, what residual risk remains, when is the next review, and what performance measure will show success? This allows maintenance crews, inspectors and designers to work from the same evidence instead of receiving a list of tasks divorced from asset condition.

6.2 Intervention selection with consequence and timing

Develop a program-level list of candidate treatments, then screen each for technical suitability, access, traffic impacts, permit needs, cost, durability and time sensitivity. A bridge with early coating breakdown and dry, accessible steel may benefit from a targeted coating strategy. A bridge with

advanced corrosion, connection defects or uncertain foundation stability requires qualified evaluation before defining treatment. The decision should be based on the mechanism, not merely its appearance.

Consequences affect timing. The same repair may be scheduled sooner on a bridge with no practical detour, high emergency access value or significant vulnerability during a seasonal flood. A work-window constraint can favor combining compatible preservation tasks if closure costs dominate. Bundling unrelated repairs without adequate diagnosis, however, can waste money and obscure whether interventions worked.

A practical preservation action plan identifies the lowest-intervention action that still controls an identified risk at acceptable performance. It also records what would trigger escalation to rehabilitation or replacement. This is especially important when a short-term treatment is selected as a bridge to a funded capital project: temporary risk management and final solution are different decisions.

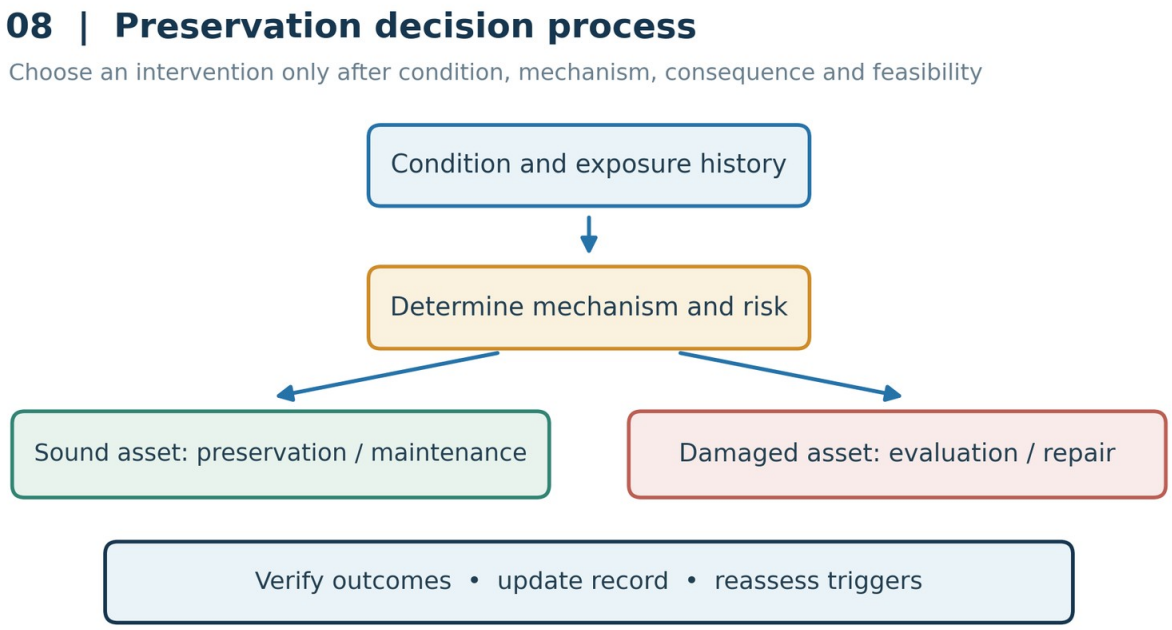


Figure 8. Select a preservation strategy after evaluating condition, mechanism and residual risk.

6.3 Compare cash flows on a common basis

A simplified present-value model provides a transparent comparison when alternatives meet equivalent performance objectives. For a future expenditure C at year n and annual real discount rate r, PV = C/(1+r)^n. If an illustrative $200,000 rehabilitation occurs at year 8 and the owner uses an assumed 3% real discount rate, PV ≈ $157,900. That number is only a financial translation of a hypothetical scenario; it is not proof the intervention will be needed or effective. Use owner-approved study periods, inflation treatment, real versus nominal rates and risk allowances.

Consider two hypothetical 20-year strategies. Strategy P has an immediate $60,000 water-control and coating program, a $35,000 intervention in year 8, and $25,000 in year 16. Strategy R has an immediate $160,000 rehabilitation and $15,000 in year 12. At an assumed 3% real rate, discounted agency

expenditures are about $103,200 for P and $170,500 for R, excluding user costs and risk consequences. These arithmetic examples are not an engineering recommendation; P is preferable only if the existing capacity, condition and expected service are consistent with the treatment plan.

A sensitivity analysis asks what happens if the expected preservation work doubles, rehabilitation advances by five years, or failure consequences materially differ. Where closure costs are high, user-cost estimates may change the ranking. A defensible decision separates cost analysis from engineering fitness and makes uncertainty visible to the owner.

6.4 Program feedback and inspection linkage

The condition database should provide an actionable connection between inspections and projects. Each finding needs a location, unique element ID, mechanism, action, priority rationale, expected completion and verification record. After work, update the condition and asset history so the next team can distinguish original damage from a completed repair. This is the basis for measuring whether the program reduces deterioration and unplanned closures.

Annual work plans should be revisited when new inspections, extreme events, changes in traffic or costs alter the risk profile. A program based only on chronological age can miss exposed younger bridges and over-treat well-performing older assets. Portfolio-level tools are useful, but they do not replace project-level engineering analysis for structures with unusual geometry, severe damage or significant consequence of failure.

Communicate the preservation strategy in accessible terms: what the owner is buying, which risks are controlled, what remains uncertain and when the decision will be reconsidered. Good technical communication is an essential part of bridge engineering because a sound recommendation can fail if the decision-maker cannot distinguish deferred work from accepted residual risk.

6.5 Integrated case: South Coast Greenway Trail Bridge

Revisit the 115-ft conceptual trail crossing from Module 2. The selected option remains provisional until required hydraulic, geotechnical, permitting and constructability evidence is approved. Design coordination includes a serviceable movement scheme, drainage away from seats, protected steel surfaces and an access path for future inspections. The erection package separates temporary stability engineering from final structural analysis. The quality plan requires verifiable release at support survey, girder erection, deck or walkway installation, and final bearing/joint acceptance.

Five years into operation, hypothetical joint leakage and coating degradation are reported at an end support. An owner who retained the baseline drawings, bearing settings, drainage details, material records and original condition photographs has a better starting point for diagnosis than one who retained only a completion certificate. The appropriate investigation must determine the water entry and extent of damage before selecting repair. A targeted solution that controls both joint leakage and affected coating may be sufficient only after confirming the underlying condition and structure.

The bridge lifecycle record now links the original planning assumptions to a service-life decision. If the crossing proves harder to access than expected, that feedback can change design criteria for the next project. The course's central practice is to connect the decisions of planning, design, construction and

preservation rather than have each stage recreate the same knowledge after the preceding team has left.

6.6 Worked example: present-value sensitivity and decision reversal

The baseline Strategy P consists of $60,000 now, $35,000 in year 8 and $25,000 in year 16. Strategy R consists of $160,000 now and $15,000 in year 12. At 3% real, their agency cost present values are calculated by discounting each future expenditure separately: P = 60,000 + 35,000/(1.03)^8 + 25,000/(1.03)^16 ≈ $103,208; R = 160,000 + 15,000/(1.03)^12 ≈ $170,521. These are illustrative nominal amounts expressed as assumed constant-dollar estimates; the study uses a real discount rate consistently. The owner must confirm that this treatment is appropriate for actual budgeting and escalation.

A scenario in which P's year-8 work rises to $80,000 produces P ≈ $138,732. A scenario in which R's future work is needed at year 6 instead of year 12 yields R ≈ $172,562. In these isolated scenarios, P remains cheaper on agency costs. But that is not evidence that P meets the same capacity, service or risk objectives as R. If P includes a material probability of unplanned closure, user costs or a structural deficiency that cannot be safely left untreated, comparing only agency cash flows is misleading. Assign uncertainty ranges to both cost and engineering fitness rather than presenting a single number as a certainty.

Now consider a condition evaluation that confirms the foundation needs major rehabilitation within two years, a consequence absent from the P budget. If this adds a hypothetical $120,000 expenditure at year 2, P increases by about $113,112 in present value, giving a total near $216,320 and reversing the agency-only ranking. The magnitude is intentionally hypothetical. It illustrates how a missing technical scope item can dominate a financial argument. A preservation recommendation must be conditioned on an adequately investigated mechanism and feasible, acceptable performance.

The decision record should explain why a cost assumption is plausible, what physical evidence supports treatment selection and which uncertainty could reverse the conclusion. An owner can then authorize a targeted investigation rather than accept a false sense of precision. The project proceeds with a decision that can be reconsidered transparently as better information becomes available.

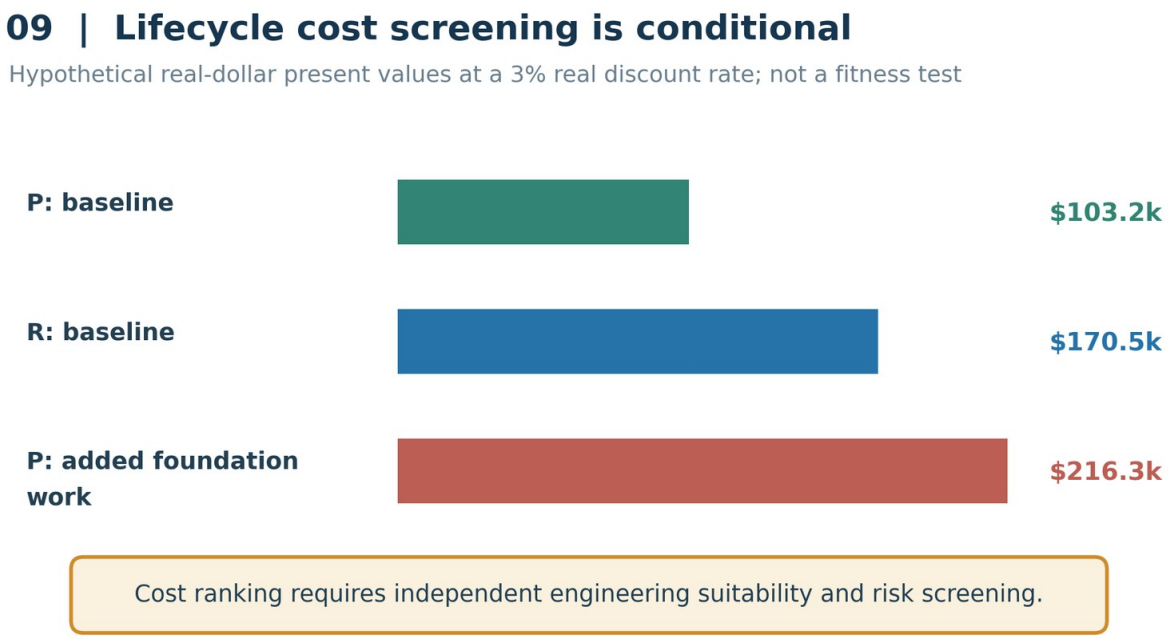


Figure 9. Illustrative present-value screening with an unforeseen foundation expenditure scenario.

6.7 Transfer lesson: design choices that reduce maintenance exposure

The lifecycle view should inform new design, not only work on existing bridges. Drainage paths, accessible bearings, removable joints, corrosion protection, inspection platforms and replaceable components can reduce future intervention burden. Designers should ask the maintenance team whether a proposed detail can be reached safely, cleaned, inspected and replaced without major disruption. The answer should be documented while changes remain practical.

A project-level post-occupancy review can examine whether water management works as intended, whether bearings move within the expected regime, how inspection access performs and whether actual work windows match the planning assumptions. This information strengthens the owner's standards for subsequent bridges. By treating preservation as a design feedback system rather than a late expense, engineers can improve long-term service outcomes.

6.8 Network consequences and preservation funding

Asset priorities cannot be set entirely from a bridge's construction cost or the size of its visible defect. A corridor may carry emergency access, school buses, agricultural equipment or an essential evacuation route. A low-volume bridge can have high consequence if the detour is long or unreliable during floods. Document who uses the facility, which closures are tolerable, what temporary operational controls exist and whether a feasible alternate crossing remains available during an event. These considerations affect inspection urgency and work packaging, although they do not replace technical evaluation of structural fitness.

For an illustrative closure assessment, suppose a local crossing serves 1,800 vehicles per day and a detour adds 7 miles. The daily extra vehicle-miles are 12,600 if all vehicles are displaced and travel the full detour. If an agency estimates an applicable user-cost rate per vehicle-mile, a transparent

screening calculation can estimate one consequence of the closure. It must still account for diverted trips, freight, time, emergency-service consequences, fuel, road conditions and uncertainty; a single uniform rate should not be used for a formal benefit-cost analysis without support. For pedestrian and trail crossings, alternative-route accessibility, user safety and disconnection effects may be more important than vehicle mileage.

Program planning should distinguish the need to preserve condition from the source of available funding. A bridge selected for a rehabilitation capital program may still need interim risk reduction, drainage maintenance or close monitoring before construction. The interim action should have a defined duration and decision trigger, with a named owner who accepts the remaining risk. Conversely, a planned preservation treatment should be revisited if the bridge is expected to be replaced soon, so the owner does not spend resources on a treatment unlikely to deliver its intended service value.

The best annual program presents an integrated portfolio: routine cyclical tasks, targeted condition-based repairs, investigation of uncertain findings, major rehabilitation and replacement projects. Each has an evidence-based trigger, responsible organization, delivery window and outcome metric. Owners can then explain why one bridge is receiving near-term drainage work while another receives a more substantial engineering evaluation, even if their overall visual ratings seem similar. This transparency supports accountable investment without pretending a single ranking formula contains every relevant fact.

6.9 Preservation measures that support continuous improvement

Program effectiveness is measured through more than the number of completed work orders. Useful indicators can include changes in recurring leakage, progression of documented section loss, cost per treated bridge element, mean time from critical observation to owner disposition, frequency of emergency closures, work-window overruns and completeness of asset records. Each indicator needs a clear definition and reliable input data. A lower count of reported defects may reflect poor inspection coverage rather than better asset condition, so interpretation must consider inspection intensity and access limitations.

A post-treatment inspection should establish whether the intended mechanism was controlled. For example, after joint sealing and drain relocation, the team can verify that water no longer reaches the bearing seat during relevant conditions, while separately assessing existing corrosion or concrete damage. A coating system may appear aesthetically intact shortly after installation but require continued observation of vulnerable edges, field splices and drainage locations. Monitoring should be proportionate to residual risk and developed by the appropriate owner or engineer; it is not a universal calendar interval.

Lessons from repeated deterioration can be carried into new capital-project standards. If a cohort of bridges shows chronic leaking joints, the design office may evaluate joint-elimination concepts or more accessible joint details; if inspection teams consistently cannot reach bearing areas, maintainability criteria can be revised. The feedback loop is most useful when the engineering office, field inspection program, maintenance staff and construction QA team share the same location-based evidence rather than separate spreadsheets with ambiguous element names.

A preservation closeout memo therefore records the original problem, the intervention mechanism, completed work, acceptance evidence, residual risk, monitoring instruction and next review trigger. A future decision-maker should be able to answer: What was wrong? What did we do? What improved? What remains uncertain? When must we look again? Those five questions transform maintenance records into an engineering asset-management resource.

Module 6 | Applied engineering workshop

Preservation investment memo (20 minutes). Using the supplied Strategy P and Strategy R amounts, reproduce the two discounted sums at 3% real over a 20-year study period, then run two sensitivity cases: increase P's year-8 treatment to $80,000, and bring R's year-12 expenditure forward to year 6. Indicate which assumptions are financial inputs versus engineering determinations. Separately write a 100–150-word recommendation for the South Coast Greenway Trail Bridge that includes an inspection trigger, a suitable diagnostic step, a treatment selection gate, responsible decision authority and a date for reassessment. Do not claim a repair is structurally sufficient without capacity and condition evidence.

Five-minute consolidation

Recompute both present-value examples and identify which assumption could overturn the preferred alternative. State in one sentence the engineering fitness gate that must be satisfied before the owner considers cost ranking.

Technical reference pointers

Related source entries: [5], [6].

Applied engineering worksheets

These optional reproductions of the module work products are provided for use during the allocated applied-work periods. They do not contain answers to the completion assessment. Record evidence and named decision responsibility rather than making unsupported acceptance judgments.

Worksheet 1 | System / load-path register

Trace deck, primary members, supports, foundations and adjacent drainage. Identify at least five interfaces.

Component / station	Evidence or drawing	Movement / loading issue	Next action / owner

Decision memo

Decision factor	Notes / supporting evidence
Observed facts and source records	
Key unknowns and potential consequences	
Authorized next action / owner	
Required closure evidence / timing	

Worksheet 2 | Alternatives and approvals

Assess concept options A, B and C against hard gates. For any "conditional" item, state the confirmation needed.

Gate or criterion	Option A	Option B	Option C

Decision memo

Decision factor	Notes / supporting evidence
Observed facts and source records	
Key unknowns and potential consequences	
Authorized next action / owner	
Required closure evidence / timing	

Worksheet 3 | Constructability / design interface log

Classify the interface, identify the physical consequence and specify closure evidence.

Issue / drawing rev.	Consequence	Decision owner	Required evidence

Decision memo

Decision factor	Notes / supporting evidence
Observed facts and source records	
Key unknowns and potential consequences	
Authorized next action / owner	
Required closure evidence / timing	

Worksheet 4 | Hold-point and nonconformance log

For each stage, establish what is observable before work is concealed or made irreversible.

Stage / location	Requirement / evidence	Authority	Disposition / release

Decision memo

Decision factor	Notes / supporting evidence
Observed facts and source records	
Key unknowns and potential consequences	
Authorized next action / owner	
Required closure evidence / timing	

Worksheet 5 | Inspection evidence-to-action

Avoid turning a symptom into an unsupported capacity claim. Name the diagnostic question.

Observation	Possible mechanism	Missing evidence	Escalation / engineer

Decision memo

Decision factor	Notes / supporting evidence
Observed facts and source records	
Key unknowns and potential consequences	
Authorized next action / owner	
Required closure evidence / timing	

Worksheet 6 | Preservation investment decision

Use consistent economic units and verify engineering fitness before cost ranking.

Alternative / year	Cash amount	Discount factor	PV / implication

Decision memo

Decision factor	Notes / supporting evidence
Observed facts and source records	
Key unknowns and potential consequences	
Authorized next action / owner	
Required closure evidence / timing	

Financial method: PV = amount / (1 + real discount rate)^year. Baseline and sensitivity cases appear in Module 6. State whether amounts are in current or constant dollars. Record technical fitness as a separate gate.

Glossary of practice terms

Abutment: End support that connects the superstructure with foundations and approach earthworks.

Asset condition: Observed state recorded through inspection; not, by itself, a load rating.

Bearing: Component transferring defined forces while allowing or restraining specified movement or rotation.

Bridge preservation: Planned maintenance-oriented action intended to slow deterioration and extend service life.

Camber: Intentional or observed shape/elevation variation that must be interpreted at its measurement stage.

Change control: Process for evaluating and authorizing deviations from the governing project baseline.

Condition-based maintenance: Work triggered by observed condition rather than a purely cyclical interval.

Constructability: Feasibility and efficiency of building the designed system under site and staging constraints.

Critical finding: An inspection issue requiring action under the applicable bridge inspection program.

Cross-frame: Transverse bracing system component that can affect stability and distribution.

Engineer of record: Responsible licensed professional as defined by applicable law and project contract.

Falsework: Temporary works supporting construction before the permanent system performs its intended function.

Fatigue: Damage accumulation related to repeated stress range and detail behavior.

Fixed point: Location intended to restrain a specified movement within the selected structural concept.

Hold point: Construction stage that cannot proceed until a defined inspection/release requirement is met.

Interface register: Controlled list of interactions among drawings, disciplines, approvals and stakeholders.

Joint: Detail accommodating movement and/or connecting portions of the bridge deck.

Load path: Sequence by which forces transfer through the structural system into supports and ground.

Load rating: Qualified structural capacity evaluation conducted under applicable standards and program rules.

NBIS: National Bridge Inspection Standards under 23 CFR 650 Subpart C.

Nonconformance: Verified deviation from a governing requirement requiring documented disposition.

Preservation trigger: Condition, observation or planned interval that prompts intervention or reassessment.

Quality assurance: Independent or owner-side evidence and controls verifying quality systems as defined by contract.

Quality control: Production-side means of verifying work meets requirements.

Rehabilitation: More significant intervention restoring or improving an asset's performance.

Scour: Erosion/removal of bed or bank material that may reduce foundation support.

Serviceability: User and operating performance such as movement, vibration, drainage and ride quality.

Substructure: Components between superstructure/bearings and foundations, such as piers and abutments.

Superstructure: Primary load-carrying elements spanning between supports.

Temporary works: Structures and systems needed for safe construction, not necessarily part of the completed bridge.

Technical sources and edition control

The sources below establish terminology, practice and reference status as of November 2026. A source cited here may not be contractually adopted on a particular project. Check the contract, jurisdiction and owner-adopted edition and applicable amendments before using any technical requirement. Public references and publishers' publication listings are not substitutes for the complete adopted specifications.

[1] AASHTO. LRFD Bridge Design Specifications, 10th ed. (2024), September 2025 errata. Publisher / agency source

[2] AASHTO. LRFD Bridge Construction Specifications, 4th ed. (2017), 2020/2022/2023/2024/2025 interim revisions. Publisher / agency source

[3] AASHTO. LRFD Steel Bridge Fabrication Specifications, 1st ed. (2023), with 2024 and 2025 interim revisions. Publisher / agency source

[4] AISC / AASHTO-NSBA. G12.1-2020 Guidelines to Design for Constructability and Fabrication; S2.1-2018 is archived. Publisher / agency source

[5] FHWA. Bridge Preservation Guide, Spring 2018; Service Life Design Reference Guide, 2022. Publisher / agency source

[6] FHWA. Bridge Inspector's Reference Manual (2022 NBIS edition; issued March 2023) and inspection resources. Publisher / agency source

[7] FHWA. Specifications for the National Bridge Inventory (2022) and June 2026 errata No. 2. Publisher / agency source

[8] US Code of Federal Regulations. 23 CFR 650 Subpart C, National Bridge Inspection Standards; qualification requirements in §650.309. Publisher / agency source

[9] FHWA. HEC-18 Evaluating Scour at Bridges, 5th ed., FHWA-HIF-12-003 (2012). Publisher / agency source

[10] FHWA. March 17, 2026 memorandum on use of updated structural design standards. Publisher / agency source