

Bridge Deck Joints: Performance and Replacement

Deck joints are where most bridges start to fail. A strip seal that tears, a compression seal that drops out of its opening, or a finger joint whose trough has filled with grit will let salt water onto bearings, beam ends, seats and pier caps that were never meant to be wet. This course covers the families of deck joints and what each one is for, how they fail, how to inspect and code them using the AASHTO element definitions, how to choose and install a replacement joint so that it lasts, and when it makes sense to eliminate the joint instead. It draws mainly on NCHRP Synthesis 319, Bridge Deck Joint Performance (Purvis, TRB 2003), a survey of 49 agencies, 35 of them state DOTs, and on the joint element and defect definitions in the Alabama DOT Bridge Element Inspection handbook (rev. 08/2014), which follows the AASHTO Manual for Bridge Element Inspection. The FHWA Bridge Preservation Guide (2018) is used for the preservation framing. Numbers in worked examples that do not come from these documents are labeled illustrative.

Learning objectives

- Classify joint types
- Diagnose leaking and failure
- Choose joint replacement strategies
- Consider jointless conversion

Why joints matter more than their cost suggests

NCHRP Synthesis 319 opens its conclusions bluntly: although the trend is to eliminate deck joints whenever possible, the vast majority of existing bridges have joints, a situation that will continue for many years, and "most bridges still have deck joints, and most deck joints have problems." The report notes that damage related to deck joints on existing U.S. bridges costs millions of dollars each year, counting both the damage to the joint itself and the damage to the parts of the bridge beneath it that are exposed to debris and contaminants.

The reason a small, inexpensive component matters so much is position. A transverse deck joint sits directly over the beam ends, the bearings, the bridge seat and the top of the pier cap or abutment. Those are exactly the details that are hardest to protect, hardest to inspect closely, and most expensive to repair. Synthesis 319 illustrates the consequence with photographs of debris piled on a pier cap, corroded steel diaphragms under a joint, a corroded steel beam end, and a frozen bearing with a damaged seat under a leaking joint. Salt water that passes through the joint keeps that debris wet and salty, and the debris holds moisture against the steel and concrete long after the deck has dried.

The report traces the rising importance of watertightness to deicing salt. Over five decades, public expectations of bare pavement grew, salt use grew with them, and the popularity of open joints decreased accordingly. Some states now treat leaking joints as an environmental issue as well as a structural one.

What a joint is supposed to do

Synthesis 319 states the goal as a joint that is quiet, smooth riding, watertight, capable of accommodating movement, as durable as the adjacent deck, and as maintenance free as possible. It adds immediately that all currently available joints require preventive maintenance to keep functioning and avoid costly structural damage. No joint meets all of those goals for

the life of the deck, which is why the maintenance and replacement sections of this course matter as much as the selection section.

The movements a joint must accommodate come from several sources, which the report lists: thermal expansion and contraction (the dominant effect), concrete creep and shrinkage (which contribute slightly and produce permanent length change), prestressing, live load bending that rotates the girder ends, and substructure settlement. Total movement is proportional to the expanding length, and movement is complicated on skewed bridges, where the deck moves along its own axis but the joint lies at an angle to it, so the joint sees both opening and racking.

Where this course fits

This course is the companion to BR-B01 (Bearings): a leaking joint is the most common reason bearings corrode and freeze. The inspection coding follows the element approach in BR-I04 (Element-Level Inspection Fundamentals), the preservation framing connects to BR-DP01 (Bridge Preservation Programs) and BR-DP02 (Deck Preservation), and the corrosion consequences for steel beam ends are treated in BR-I07.

Joint classifications

Synthesis 319 begins by sorting deck joints by function before sorting them by product. The distinctions are worth keeping straight because inspectors and designers sometimes use "joint" loosely.

Construction joints

Construction joints, or cold joints, separate stop and start locations during concrete placement. They are located on plans near points of contraflexure in continuous decks, and reinforcing steel continues through them as if they were not there. Built properly, they are difficult to detect, of little consequence, and leak little. If the two faces do not bond, water penetrates as it would through a crack.

Contraction joints

Contraction joints control shrinkage so cracking occurs at the joint. They are found in sidewalks and retaining walls, sometimes with a water stop, and the report notes they are generally not used in bridge decks. If they were, the top of the crack would need to be sealed to protect the reinforcement.

Joints over fixed bearings

A joint over a fixed bearing allows the beam end to rotate but prohibits translation. These joints are typically narrower than expansion joints. They still need to be sealed, because a fixed joint that leaks wets the fixed bearing and seat just as effectively as an expansion joint does.

Joints over expansion bearings

Expansion joints accommodate rotation and translation. The report describes two design responses to movement: minimize or eliminate joints and design the superstructure and substructure for the resulting forces, or provide openings perpendicular to the significant movement at span ends to accommodate expansion, contraction and rotation. The rest of the synthesis, and the rest of this course, is about the second approach and when to switch to the first.

Open versus closed

The most useful practical classification is whether the joint is meant to pass water or stop it.

- **Open joints** (butt, sliding plate and finger joints) protect the deck edges and carry traffic across the gap but let water and debris through. They may include a drainage trough beneath.
- **Closed joints** (field-molded sealers, compression seals, strip seals, asphalt plug joints, inflatable seals, cushion seals and modular joints) are meant to be watertight and so protect the components below.

The survey showed that agencies do not draw the line identically. Several respondents said the sliding plate is not intended to be watertight and belongs with the open joints, and many considered a finger joint with a trough to be effectively a closed system.

Open joints: butt, sliding plate and finger

Synthesis 319 gives typical movement ranges for each open joint type. These ranges are as reported in the 2003 synthesis and are a guide to how each type is normally used, not design limits.

Type	Typical movement (Synthesis 319)	Main weaknesses reported
Butt joint	Less than 25 mm (1 in.)	Edge spalling or raveling; armor angles dislodge
Sliding plate	25 to 75 mm (1 to 3 in.)	Plates loosen, become noisy, detach
Finger (tooth)	Greater than 75 mm (3 in.)	Concrete deterioration around joint; bent fingers; trough maintenance

Butt joints

Butt joints are used where only rotation with minor thermal movement must be accommodated, because they provide no transition for traffic across the gap. Armor, usually a metal angle embedded along each top edge and anchored with studs, bolts or bars, is typical but not universal. The synthesis identifies two built-in difficulties: protecting the metal facing from corrosion, and getting concrete properly consolidated under the angle. Over time the angles may become dislodged because of inadequate support or fatigue of the anchor attachments, and the loose metal becomes a traffic hazard. Unarmored butt joints spall and ravel at the top edge, and once damage begins it increases until repair. Agencies routinely upgrade butt joints when decks are rehabilitated, sometimes removing the armor, replacing it with elastomeric (polymer) concrete, and redesigning the opening to hold a watertight sealer.

Sliding plate joints

Sliding plate joints were at one time the predominant type for steel-framed structures. A plate attached to one side extends across the opening and rests in a slot on the other side. The joint is not watertight but keeps most debris out of the opening. The synthesis lists a chain of problems: inadequate consolidation leaves the plate without support and with poor anchorage; noncompressible debris accumulates in the slot at the free end and pries up the unsupported edge; anchors corrode and fatigue under traffic impact; snowplow blades damage plates and anchors; and deterioration of the surrounding roadway increases impact. The result is plates that loosen, become noisy and occasionally detach completely. The report found sliding plates particularly unsatisfactory on highways with significant truck traffic, the joint type survey respondents avoided most, and in most places already replaced by other types.

Finger joints

Finger joints carry larger movements with interlocking plates cantilevered from both sides. Their initial cost is considerably less than a closed joint of the same capacity, and that difference is much larger when the alternative is a modular joint. Because modular joints have had significantly more durability problems, the synthesis reports that many agencies opt for finger joints with drainage troughs on longer spans. Finger joints tend to have fewer problems than many other joints. Problems that do occur include anchorage problems and fingers bending upward, which cause noise, roughness and occasionally broken fingers. The most common problem is deterioration of the concrete around the joint. Because the joint is open, the only protection for the elements below is a properly maintained trough.

The trough problem

The synthesis states the main reason most agencies avoid open joints: they permit corrosive contaminants to drain through the deck. Troughs help, but "on most bridges they introduce another set of problems." A trough that fills with debris overflows onto the very seats it was meant to protect, a corroded or disconnected trough drains onto a bearing, and troughs are often hard to reach for cleaning. A finger joint with a trough is only as good as the trough maintenance program behind it.

Closed joints: field-molded, compression and strip seals

The synthesis describes closed joints as systems that also protect the components below from water, salt and other roadway contaminants. Among them it found no consensus on which works best. Systems have evolved over decades: sealer materials have improved, anchors are stronger and better designed, installation methods have been refined, and the blockout material holding some systems in place has changed. Performance also depends on climate, traffic volume and size, snow-removal methods, construction skill and maintenance.

Field-molded (poured) sealers

Field-molded sealers were among the first watertight joints. A thick, pourable waterproof material is placed near the top of the joint over a premolded filler (backer rod) that keeps it from flowing through. Once cured it remains flexible and bonds to the sides of the opening. Synthesis 319 reports these sealers are traditionally used on openings of 25 mm (1 in.) or less with movement of about 5 mm (3/16 in.) or less, though newer materials are marketed for larger movements. The first poured seals, heated asphalt and coal tar products, did not perform well; early polymers had the same problems of debonding, splitting and damage from noncompressible debris, and failure of the deck edge took the sealant with it. Current systems typically combine an elastomeric header with a pourable silicone sealant and polyethylene foam backer. Agencies reported that when installed properly the newer systems serve well, and the type was returning to widespread use.

Compression seals

Compression seals rely on a continuous preformed neoprene section (open-cell neoprene or closed-cell dense foam in some products) compressed into the opening for the full width of the deck. The synthesis gives a movement range of about 5 to 60 mm (0.25 to 2.5 in.). Because the seal works only while it is compressed, its success depends on the opening being the right width for the deck temperature at installation, with vertical sides and straight, parallel edges for the full length. The synthesis singles out compression seals in that respect. In the survey they were the second most popular closed joint, behind strip seals. A common failure is the seal losing compression in cold weather and dropping or walking out of the opening.

Strip seals

A strip seal consists of a premolded neoprene gland mechanically locked into steel extrusions anchored to the deck on both sides. The synthesis gives a movement capacity of up to 100 mm (4 in.). The strip seal was the joint survey respondents found least problematic and the one favored for short-to-moderate continuous spans by most owners. The gland can be replaced without removing the extrusions if the rails are sound, which makes the strip seal one of the more maintainable joints. Its weaknesses are the anchorage of the steel rails (a recurring theme for all armored closed joints), gland punctures from debris, gland pull-out, and snowplow damage, particularly where the skew matches the plow blade angle.

Inflatable seals

Inflatable neoprene open-cell seals are similar to compression seals, except compressed air holds the seal in place against the joint faces while the adhesive cures. They were among the newer systems some agencies were testing.

Closed joints: plug, cushion and modular

Asphalt plug joints

An asphalt plug joint is a band of polymer-modified asphalt compacted into a blockout centered over the joint opening, usually over a plate that bridges the gap. Synthesis 319 gives a movement range of less than 50 mm (2 in.). Plug joints ride smoothly and can be installed relatively quickly, which makes them attractive on asphalt-overlaid decks. Several agencies were testing them in 2003, and one rehabilitation strategy reported was replacing compression joints with asphalt plugs. They are sensitive to temperature, to the quality of material and compaction, and to traffic that can push or rut the binder; users should rely on current agency specifications for limits.

Cushion seals

Cushion seals are steel-reinforced neoprene pads recessed into the deck over the opening and bolted to both sides. The synthesis gives a capacity of up to 100 mm (4 in.). After the sliding plate, the cushion seal was the closed joint type survey respondents avoided most. The segments are spliced end to end, so splices are unavoidable, and the report shows snowplow damage to a cushion joint as a typical problem.

Modular joints

Modular joints are used for movements over 100 mm (4 in.). They consist of multiple seals separated by steel separator (center) beams that are carried on support bars spanning the opening, with springs and bearings controlling the gap. The synthesis reports that about 60% of respondents specified modular systems; those that did not most often cited cost, and several cited poor performance. Problems reported included weld failures, anchor failures, support beam failures, spring failures and gland failures. The consensus was that modular joints are still the best available option for large-movement decks and have improved with experience and research, including NCHRP Report 402 on fatigue design of modular joints, which the synthesis cites. For long spans the synthesis concluded there are only two choices, finger or modular, chosen by roughly equal numbers of respondents: owners for whom cost is the priority prefer the finger joint with a trough; those who demand watertightness choose the modular system.

Summary of closed joint ranges

Type	Typical movement (Synthesis 319)
Field-molded sealer	Openings 25 mm (1 in.) or less; movement about 5 mm (3/16 in.) or less traditionally

Compression seal	5 to 60 mm (0.25 to 2.5 in.)
Asphalt plug	Less than 50 mm (2 in.)
Strip seal	Up to 100 mm (4 in.)
Cushion seal	Up to 100 mm (4 in.)
Modular	Over 100 mm (4 in.)

In the survey, the closed joints specified most often for movements under 150 mm (6 in.) were, in order of preference, strip seal, compression seal, silicone field-molded seal and asphalt plug. Only one responding agency, Mississippi, reported that it did not specify closed joints at all.

What the survey found about performance

The Synthesis 319 survey was sent to all state DOTs, all Canadian provinces and selected agencies worldwide, and drew 49 responses including 35 from state DOTs. Its findings are now more than two decades old, but they describe patterns that inspectors still see and they explain why current practice looks the way it does.

Leakage is the rule, not the exception

Asked what share of their closed joints leak, ten respondents said 75% to 100%, eight said 50% to 75%, six said 25% to 50%, and seven said 0% to 25%. More than a third declined to estimate. On timing, fifteen respondents said closed joints begin leaking within five years of installation, ten said five to ten years, and only one said more than ten years. Respondents attributed leakage to improper installation, poor maintenance, puncture or damage by debris, joint type, defective product, traffic damage, snowplow damage and temperature extremes.

Debris

Almost all respondents said debris commonly collects in their joints, and 80% said it adversely affects performance. Debris punctures glands, fills compression seals, packs the slot of sliding plates, and, if it fills a joint completely, prevents closing. One of the noteworthy problems respondents listed was debris in joints causing lengthening of the deck and substructure damage: a joint that cannot close transfers expansion force into the backwall and substructure.

Movement capacity

Respondents were evenly split on whether they had seen problems from inadequate movement capacity. Those who had cited installation at the wrong temperature, substructure movement, skewed bridges, jammed joints and incorrect design. Compression failure when a joint closes was also listed.

Defining failure

More than half of respondents defined joint failure as leakage. For some agencies the only failure criterion was a traffic hazard, and some included physical damage. The difference matters: an agency that treats a leaking joint as working until it becomes a hazard will see much more damage below the deck than one that treats leakage as failure.

Construction practices

The survey showed conflicting preferences, with some agencies recommending elastomeric headers and others avoiding them, some recommending armor and others not. Recurring suggestions included using a closure pour or blockout to install or

replace a joint, setting the sealer so it is relaxed at the median ambient temperature, consolidating concrete under armor, using strong fatigue-resistant anchors, protecting against snowplows, following manufacturers' recommendations, prohibiting splices in premolded seals, setting seals at the proper elevation, and installing troughs under closed seals to handle inevitable minor leakage. Thirty respondents prohibited field splicing of premolded seals, four allowed it only for staged construction, and ten allowed it without exceptions. Welded studs were the most common anchorage, followed by steel straps and reinforcing bars. Where agencies had special blackout concrete requirements, elastomeric (polymer) concrete was the most commonly used product.

Inspecting joints: the element approach

Under the AASHTO element-level approach (see BR-I04), joints are inventoried as elements measured in linear feet along the joint, and each foot is assigned to one of four condition states based on defects. The Alabama DOT handbook, which follows the AASHTO Manual for Bridge Element Inspection, lists seven joint elements:

Element	Name
300	Strip Seal Expansion Joint
301	Pourable Joint Seal
302	Compression Joint Seal
303	Assembly Joint with Seal (for example modular)
304	Open Expansion Joint
305	Assembly Joint without Seal (for example finger or sliding plate)
306	Other Joint

The parenthetical examples for 303 and 305 reflect common usage; check your agency's coding guide for how it assigns specific products.

Joint defects

The handbook defines the joint defects as follows:

- **2310 Leakage:** leakage through or around sealed joints.
- **2320 Seal Adhesion:** loss of adhesion in sealed joints.
- **2330 Seal Damage:** damage to the rubber in joint seals.
- **2340 Seal Cracking:** cracking in the rubber.
- **2350 Debris Impaction:** accumulation of debris in joint seals that may or may not affect performance.
- **2360 Adjacent Deck or Header:** concrete deck damage in the area anchoring the joint.
- **2370 Metal Deterioration or Damage:** metal damage or deterioration in the joint.
- **7000 Damage:** impact damage, with the resulting material damage captured under the appropriate defect.

Condition state definitions

Defect	CS1 Good	CS2 Fair	CS3 Poor	CS4 Severe
2310 Leakage	None	Minimal; minor dripping through the joint	Moderate; more than a drip and less than free flow	Free flow of water through the joint

2320 Seal Adhesion	Fully adhered	Adhered for more than 50% of joint height	Adhered 50% or less but still some adhesion	Complete loss of adhesion
2330 Seal Damage	None	Abrasion without punctures	Punctured, ripped or partially pulled out	Punctured completely through, pulled out or missing
2340 Seal Cracking	None	Surface crack	Crack partially penetrating the seal	Crack fully penetrating the seal
2350 Debris Impaction	None to a shallow cover of loose debris not affecting performance	Partially filled with hard-packed material but still allowing free movement	Completely filled and impacts joint movement	Completely filled and prevents movement
2360 Adjacent Deck or Header	Sound; no spall, delamination or unsound patch	Edge delamination or spall 1 in. or less deep or 6 in. or less in diameter; no exposed rebar; sound patch	Spall greater than 1 in. deep or greater than 6 in. diameter; exposed rebar; delamination or unsound patch that makes the joint loose	Spall, delamination, unsound patch or loose anchor that prevents the joint from functioning as intended
2370 Metal Deterioration or Damage	None	Freckled rust; no cracks or impact damage; connection may be loose but functioning	Section loss, missing or broken fasteners, cracking or impact damage but still functioning	Cracking, section loss, damage or connection failure that prevents the joint from functioning

Two features of these definitions deserve attention. First, the leakage defect is the one that tells the owner whether the joint is doing its main job, so inspectors should look from below, ideally after rain, for staining, wet seats, efflorescence and drip marks, not only at the seal from the deck. Second, the CS4 definitions for 2350, 2360 and 2370 all turn on whether the joint can still function. A joint packed solid with debris is in CS4 for 2350 even if the gland is intact.

What to look for in the field

Synthesis 319 found that inspection of joints in the U.S. usually happens at the routine two-year interval and that inspectors mostly look for physical damage. Follow-up interviews suggested agencies tend not to respond to joint problems unless there is a safety hazard or the deck is being rehabilitated. That pattern is the main argument for inspecting joints with preservation in mind: the time to act on a joint is when it first leaks, not when its armor comes loose.

From the deck

- Gland or seal: tears, punctures, pull-out from the rail, missing sections, cracking, loss of adhesion on poured seals, compression seals that have dropped below the surface or walked out.
- Debris: depth and hardness of debris in the gland or opening, stones lodged in compression seals, packed slots under sliding plates.
- Armor and rails: loose, cracked or missing anchors, rails that rock or ring under traffic, cracked welds, bent fingers, loose or missing bolts on cushion or finger plates, section loss.
- Headers and blockouts: spalls, delaminations (sound with a hammer or chain), cracking along the blockout interface, debonded polymer nosing, potholes at the joint.
- Ride: bump or dip at the joint, noise under trucks.
- Opening: measure the gap and record the temperature. Compare with expected opening; an unusually wide or narrow gap may signal substructure movement, a jammed joint, or a bearing problem.

- Curbs, barriers and sidewalks: how the seal turns up or passes through, damage where the joint meets the parapet.

From below

- Staining, wet areas, efflorescence and rust trails on the backwall, seats, pier cap, girder ends and bearings.
- Debris accumulation on seats and caps, which indicates a leak (or an open joint) and holds moisture.
- Condition of troughs: fill level, corrosion, outlets, disconnected downspouts, overflow paths.
- Bearing condition and position, since joints and bearings fail together (BR-B01).
- Beam end corrosion and section loss on steel girders, and spalling or cracking at the ends of concrete beams (BR-I07, BR-I08).

Recording for decisions

Record leakage observations with the weather. A dry seat in a drought says little. Photograph each joint from the deck and from below at the same points every cycle, measure openings with a temperature reading, and note maintenance needs separately from condition so they reach the maintenance crew rather than waiting for the next deck project.

Testing new joints for watertightness

Several survey respondents said leaking joints on new bridges were not uncommon, and agencies responded by adding performance requirements: the new joint must be shown not to leak before it is accepted. Synthesis 319 reproduces four state provisions as they stood in 2003. They are useful models for writing or reviewing a special provision, but current versions should be obtained from the agencies.

Iowa vacuum test

Iowa's IA-VAC method applies a vacuum above the seal with a chamber about 6 in. by 48 in. by 2 in. The surface and seal are wetted with a water and shampoo solution, foam blocks plug the ends of the opening under the chamber if the seal is more than 1/8 in. below the surface, and the operator stands on the chamber until vacuum registers. Bubbles indicate leaks. The tester records location, vacuum reading, number of leaks and cause.

New York watertight integrity test

At least five work days after installation, the contractor tests the full joint length. Water is ponded or flowing over the entire joint for at least 15 minutes, and the underside is inspected during that time and for at least 45 minutes after the water stops. Watertightness means no free dripping water on any surface beneath the joint; patches of moisture are not cause for rejection. Leaks are located and fixed at the contractor's expense and the test repeated under the same conditions.

North Carolina water test

The roadway portion, curb to curb, is covered with at least 1 in. of ponded or flowing water. Sidewalks are diked and a hose delivering about 1 gallon per minute runs water across the sidewalk and down the curb face. The water is maintained for 5 hours. The seal is considered watertight if no obvious wetness appears on the engineer's finger after touching underdeck areas; damp concrete that does not wet the finger is not leakage. Repairs and retests are at the contractor's expense.

Utah

Utah's provision requires that joint areas hold water for 2 hours without leakage.

Lessons for specifications

The four provisions differ widely in duration, from 15 minutes of flow plus 45 minutes of observation to 5 hours, and in acceptance criteria. Whatever method is chosen, a test written into the contract shifts the cost of a leaking new joint to the party who installed it, and it forces the curb, barrier and sidewalk portions, where leaks often occur, to be checked too. Synthesis 319 frames the minimum objective as ensuring that the seal is watertight when it is placed.

Lessons for long joint life

Chapter 6 of Synthesis 319 lists the practices that most distinguished agencies with long-lived joints. The report notes that climate, truck volume, snowplow use and deicing are not controllable, but "the difference between the satisfactory and unsatisfactory performance of an expansion joint seal is often controllable by the bridge owner."

1. Run a proactive maintenance program

Preventive maintenance means washing decks, keeping drains open, removing debris and fixing small problems, such as a loose anchor or an unbonded seam, before they become failures. The report argues that it must be agency policy promoted by top management to happen, and that a leaking seal is not "better than no seal" any more than a leaking roof is better than no roof: the objective is a watertight seal, and a seal should be repaired if any part leaks. All ten survey respondents with joint maintenance programs considered them cost-effective, and interviews suggested many others would agree but lacked funding. The report pictures a compression seal on a bridge over the New York State Thruway installed in 1986 and still watertight, with the seats and beam ends beneath in excellent condition.

2. Use blockouts

A blockout is a section of deck adjacent to the joint that is removed or not cast. It allows the opening to be sized and the anchorage positioned correctly, permits a more durable edge material, lets the joint be cast after dead load deflection and shrinkage have occurred, and makes it easier to set the joint at the right elevation for ride. Many joint failures are failures of the deck material around the joint, and blockouts allow better material to be used. Many agencies reported good results with elastomeric (polymer) concrete in blockouts.

3. Bond to sound concrete

"A newly replaced joint system is no better than the adjacent bridge deck concrete." Casting a new blockout against salt-contaminated or unsound concrete fails the same way a patch in a bad deck fails, and the report notes the corrosion-cell effect where new and contaminated concrete meet. Armor that is not fully supported because of voids flexes under traffic, which accelerates fatigue and anchorage failure. Anchors should be recessed below the surface to protect against plows.

4. Set the seal for the temperature

A seal must open without damage to the maximum winter opening and close or buckle without damage at the hottest summer opening. If it is set at midrange on a very hot day, it may not stretch far enough on a very cold day. Quality control must confirm that the seal or rails are set for the temperature at the time of installation.

5. Build the opening to the right size and shape

The opening must be the correct width for the deck temperature when measured, with vertical sides and straight, parallel edges, which is critical for compression seals. When replacing a compression seal, measure the actual opening and record

deck temperature. When saw cutting a new opening, fix a template to the deck and use a two-blade saw for uniform width.

6. Install the joint after the overlay

Casting a dam around the joint and overlaying up to it, or embedding the joint in the overlay, tends to give a rough ride. Placing the overlay across the joint, saw cutting a blockout and casting the joint into it gives a smoother result.

7. Protect against unusual movement

Embankment pressure, settlement, scour or earthquakes can open or close a joint beyond design. The substructure must be stabilized and bearings repositioned first; then the opening can be restored by saw cutting or recasting, or occasionally a wider seal used.

8. Follow manufacturers' recommendations

Crews tend to install new products with familiar methods. A manufacturer's representative at the first installation helps, and recommendations should be followed unless there is good reason not to.

9. Avoid splices

Most agencies prohibit splices in premolded seals. Staged construction needs planning so the seal can be installed full length after the whole deck width is built, for example by delaying the blockout saw cut. Some agencies allow splices in curb, sidewalk or rail areas, which rarely need replacement.

10. Protect against snowplows

Joints skewed at the same angle as plow blades suffer most. Minnesota and Wyoming have installed recessed metal plates or extrusions along the joint edge to keep blades off the seal.

Choosing a replacement strategy

The survey found that half of agencies had a joint rehabilitation strategy and half did not, but the outcomes were similar: most work was reactive or tied to deck rehabilitation. Sixty-five percent tried to reduce joints when decks were rehabilitated. Almost all replaced one joint type with another during rehabilitation; examples included replacing steel plate and finger joints with strip seals and replacing compression joints with asphalt plugs. Only Maine and Alberta reported not changing types.

A decision sequence

1. **Confirm the movement.** Measure openings at known temperatures, review plans for expansion length and bearing arrangement, and check that bearings are free (BR-B01). Movement capacity is the first factor agencies listed when selecting a joint.
2. **Find the cause of the current failure.** Debris, plow damage, failed anchorage, bad blockout concrete, wrong installation temperature and substructure movement each call for different fixes. Replacing a seal without fixing the cause repeats the failure.
3. **Consider repair before replacement.** A strip seal gland can often be replaced in sound rails; a debonded poured seal can be removed and reinstalled; debris can be cleaned out. These are maintenance actions that keep a joint watertight cheaply.
4. **Consider elimination.** If the deck is being rehabilitated anyway, check whether the joint can be removed by link slab, deck continuity, or conversion to an integral or semi-integral abutment (see below).

5. **Select the replacement type.** Use the movement range, skew, traffic, plow exposure, staging, closure time, ride and maintainability. The survey list of selection factors, in order of importance, began with movement range, bridge span, type of bridge, performance and previous experience, durability, maintenance requirements and alignment, followed by curb and barrier details, initial cost, climate, expected life, installation time, life-cycle cost, support type and service level.
6. **Detail the blackout and anchorage.** Remove unsound and contaminated concrete, specify durable blackout material, fatigue-resistant anchors and recessed hardware.
7. **Specify quality control and a watertightness test.** Include setting temperature tables, opening tolerances, splice prohibition and a water or vacuum test.
8. **Plan the troughs and drainage.** Decide whether a trough is needed under a closed seal for minor leakage, and how the joint ends at barriers will drain.

Joint elimination and jointless conversion

Synthesis 319 reports that eliminating joints is a high priority for many agencies and that only three respondents did not consider minimizing joints on new bridges. A few reported maximum continuity lengths between 90 and 150 m (300 and 500 ft), though much longer continuous structures have been built. Eliminating a joint changes the rest of the bridge: respondents most often cited integral abutments, followed by orienting piles for weak-axis bending, single rows of piles, more flexible substructures, changed bearings and adjusted approaches. The synthesis cautions that on a continuous structure the movement formerly taken at the deck joint is transferred somewhere else, which may be off the bridge at the approach slab or pavement, so the approach detail must be designed for it.

For existing bridges, common conversions include closing joints over piers by making the deck continuous with a link slab, and converting end joints by making the abutment integral or semi-integral and moving the joint to the end of the approach slab. Each requires an engineering check of the superstructure for continuity effects, the substructure for the forces formerly relieved by the joint, and the bearings for the new movement pattern.

Worked example: planning a joint replacement (illustrative)

All numbers in this example are illustrative and do not come from Synthesis 319 or any agency standard.

Situation. A three-span continuous steel girder bridge has compression seals at both abutments. Inspection from below found rust staining and wet debris on both seats and freckled rust with light section loss on the bottom flanges near the bearings. From the deck, the inspector found the seal at the south abutment had dropped about 1 in. below the surface over half its length, and the seal at the north abutment was intact but packed with sand and stones over about a third of its length. Header concrete at the south end had several spalls about 1.5 in. deep, one with exposed reinforcement.

Coding (Element 302, 40 ft per joint, illustrative).

- South: 2310 Leakage, moderate flow across about 20 ft (CS3) and minor dripping elsewhere (CS2 for 20 ft). 2360 Adjacent Deck or Header: spalls greater than 1 in. deep with exposed rebar across about 8 ft (CS3). Under the AASHTO approach, the worst defect at each foot controls, giving roughly CS2 for 12 ft and CS3 for 28 ft, subject to the agency's specific rules for combining defects.
- North: 2350 Debris Impaction, partially filled with hard-packed material but still allowing free movement over about 13 ft (CS2); 2310 minor dripping at the same location (CS2); remaining 27 ft in CS1.

Diagnosis. Measured openings at both ends, recorded with a deck temperature of 45°F (illustrative), were about 3/8 in. wider than the plan opening for that temperature. The south seal was likely undersized for the actual opening or installed at a warm temperature, so it loses compression in cold weather. The north seal shows the debris problem the synthesis describes. Bearings were checked and found free.

Options considered.

1. Replace both compression seals in kind after cleaning and resizing to the measured opening. Low cost, but the opening edges at the south end are spalled, and compression seals need straight, parallel faces.
2. Rebuild both ends with polymer concrete blockouts and strip seals. Higher cost, but strip seals were the least problematic closed joint in the survey, the gland is replaceable, and blockouts allow sound edges and correct setting.
3. Convert to semi-integral abutments with the joints moved to the end of the approach slabs. Highest cost and requires an engineering study of the substructure and approach.

Decision (illustrative). Because a deck overlay is planned within two years, the owner chooses option 2 to be built after the overlay, consistent with the synthesis lesson to install the joint after placing the overlay. In the meantime, the maintenance crew cleans the north joint, resets the south seal with an interim poured silicone repair over backer rod where the edges allow, and washes the seats. The special provision requires removal of all unsound and chloride-contaminated concrete in the blockout area, recessed anchors, rail setting by temperature, no splices in the gland, and a flood test of the full length including curbs, with retest at the contractor's expense.

Maintenance program checklist

This checklist pulls together the practices from Synthesis 319 and the element definitions into routine actions. Frequencies are illustrative and should follow agency policy.

Every inspection

- Code joint elements 300 to 306 by linear foot using defects 2310 to 2370 and 7000.
- Inspect from below for leakage evidence; note weather.
- Measure openings with temperature at marked locations.
- Report maintenance needs (cleaning, small repairs) separately so they are scheduled.
- Check bearings and beam ends under each joint.

Annually or seasonally (illustrative)

- Clean debris from joints and glands, especially after winter sanding.
- Wash seats, caps and beam ends under joints, and clean troughs and outlets.
- Check anchors and bolts on finger, plate and modular joints; tighten or replace.
- Repair small seal tears, unbonded poured seals, and header spalls before they spread.

At replacement or rehabilitation

- Fix the cause, not just the seal.
- Consider eliminating the joint.
- Use blockouts, sound concrete and durable header material.
- Set for temperature, build the opening square and straight, avoid splices.
- Protect against plows on skews matching blade angles.

- Require a watertightness test and record the as-built opening and temperature.
- Update the element inventory with the new type.

Key takeaways

- Most bridges have deck joints and most deck joints have problems; the damage they cause is mostly to the bearings, beam ends and seats beneath them.
- Open joints (butt, sliding plate, finger) pass water and depend on troughs; closed joints (poured, compression, strip, plug, cushion, modular) are meant to be watertight.
- Synthesis 319 found the strip seal the least problematic closed joint and the sliding plate the most avoided joint type.
- For long spans the choice is finger joint with trough (cost) or modular joint (watertightness).
- Survey respondents reported many closed joints begin leaking within five years, with improper installation, poor maintenance and debris the leading causes.
- Element-level inspection codes joints 300 to 306 by linear foot with defects 2310 to 2370; leakage should be judged from below.
- Long joint life depends on proactive maintenance, blockouts, sound concrete, temperature-correct setting, correct openings, installing after overlays, avoiding splices and protecting from plows.
- Joint elimination moves movement elsewhere; the approach and substructure must be designed for it.

References

1. NCHRP Synthesis 319, Bridge Deck Joint Performance, 2003
2. FHWA, Bridge Preservation Guide: Maintaining a Resilient Infrastructure to Preserve Mobility, FHWA-HIF-18-022, 2018
3. FHWA, Bridge Inspector's Reference Manual (BIRM), FHWA-NHI-12-049, 2012 (as revised)
4. Purvis, R., NCHRP Synthesis 319: Bridge Deck Joint Performance, Transportation Research Board, 2003
5. Alabama DOT Maintenance Bureau, Bridge Element Inspection (element and condition state definitions following the AASHTO Manual for Bridge Element Inspection), revised 08/2014

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