Joint anchorage — each side of the deck joint assembly anchored permanently to the structure in order to transfer all static and dynamic loads from the joint assembly to the structure.

Joint seal — a poured or preformed elastomeric component designed to prevent moisture and debris from penetrating joints.

Laminated bearing — a bearing made from alternate laminates of elastomer and reinforcing material, fully bonded together during vulcanization.

Longitudinal joint — a joint provided to separate a deck into two independent longitudinal structural systems.

Open joint — a structural discontinuity that permits the passage of water and debris.

Plain bearing pad — a pad made only of elastomer.

Pot bearing — a bearing consisting of a metal piston supported by a single moulded disc of unreinforced elastomer confined within a hollow metal cylinder.

Sealed joint — a structural discontinuity that does not permit the passage of water and debris through the joint.

Shape factor — the ratio of the area of the loaded face of a bearing and the area of an elastomeric layer around the perimeter of the bearing that is free to bulge.

Sliding bearing — a bearing that accommodates differential translation.

Spherical bearing — a bearing comprising two spherical metal surfaces in contact with and sliding on matching curved surfaces.

Translation — horizontal movement of a bridge in the longitudinal or transverse direction.

Volume control joint — a joint assembly that comprises an elastoplastic material that seals and controls the deck joint opening by its ability to vary its shape at constant volume.

Zero movement point — a stationary point to which movements resulting from volumetric changes in the structure are related.

11.3 Abbreviations and symbols

11.3.1 Abbreviations

The following abbreviations shall apply in this Section:

FLS — fatigue limit state

PTFE — polytetra fluoroethylene polymer

SLS — serviceability limit state

ULS — ultimate limit state

11.3.2 Symbols

The following symbols shall apply in this Section:

A_e = lamina area of elastomeric bearing, mm^2

D = diameter of the loaded contact surface of a spherical bearing projected on the horizontal plane, mm

D_c = dimensionless coefficient relating shear strain in elastomer to axial load

D_d = diameter of elastomeric element in a disc bearing, mm

D_e = lamina diameter of a circular elastomeric bearing, mm

D_p = internal diameter of pot in a pot bearing, mm

D_r = dimensionless coefficient relating shear strain in elastomer to relative rotation of top and bottom bearing surfaces

D_1 = diameter of the curved surface of a rocker or roller unit, mm

D_2 = diameter of the curved surface of a mating unit, mm

E_s = modulus of elasticity of steel, MPa

E_b = bulk modulus of elastomer, MPa

e = induced eccentricity of the loading on a bearing, mm

$F_{srt,A}$ = constant amplitude fatigue threshold for detail Category A, MPa

F_y = yield strength of steel, MPa

f_{hyd} = maximum hydrostatic stress in elastomer, MPa

f_L = compressive stress due to live load at SLS, MPa

f_s = compressive stress due to total load at SLS, MPa

G = shear modulus, MPa

H = horizontal load on a bearing or restraint at SLS, N

h_e = total effective elastomer thickness, mm

h_f = thickness of the part of the confined sliding material that is free to bulge, mm

h_i = thickness of interior elastomer layer, mm

h_r = depth thickness in a pot bearing, mm

h_s = thickness of the sliding material, mm

K = bulk modulus, MPa

L = smaller dimension of a rectangular bearing in plan, mm; length of contact of a cylindrical surface, mm

L_e = lamina dimension of an elastomeric bearing perpendicular to the axis of rotation under consideration, mm

n = number of interior elastomer layers in laminated bearing

P_s = total load at SLS, N

P_{ud} = minimum dead load at ULS, N

p_u = average pressure on the elastomer in a pot bearing at ULS, MPa

R = radius of a curved bearing contact surface, mm; radius of a circular bearing, mm

S = shape factor of the thickest layer of elastomer or of the thickness of a plain bearing pad

T_b = thickness of the pot base in a pot bearing, mm

t_s = thickness of steel lamina, mm

t_w = thickness of the pot wall in a pot bearing, mm

$V_{c,d}$ = shear strain in elastomer due to compression from dead loads

$V_{c,l}$ = shear strain in elastomer due to compression from live loads

$V_{r,d}$ = shear strain in elastomer due to rotation from dead loads

$V_{r,l}$ = shear strain in elastomer due to rotation from live loads

$V_{s,d}$ = shear strain in elastomer due to shear deformation from dead loads

$V_{s,l}$ = shear strain in elastomer due to shear deformation from live loads

V_{total} = total shear strain in elastomer

W = larger dimension of a rectangular bearing, mm

W_e = lamina dimension of an elastomeric bearing parallel to the axis of rotation under consideration, mm

w = height of the piston rim in a pot bearing, mm

β = effective friction angle, degrees

Δ_s = total horizontal deformation of the bridge deck at SLS, mm

ε_a = axial strain due to total axial load at SLS

θ_s = relative rotation of the top and bottom surfaces of a bearing at SLS including tolerances, radians

θ_u = relative rotation of the top and bottom surfaces of a bearing at ULS including tolerances, radians

λ = compressibility index of elastomer

μ = coefficient of friction

ϕ = resistance factor

11.4 Common requirements

11.4.1 General

Deck joints and bearings shall be designed to resist loads and accommodate movements at SLS and ULS, except where superseded by the requirements of Section 4. The movements and loads shall be in accordance with the requirements of Section 3. Design of steel components shall be in accordance with the requirements of Section 10, unless otherwise specified in this section.

The selection and layout of the joints and bearings shall be consistent with the designed articulation of the structure. The articulation shall accommodate all anticipated deformations induced by loads, restraints, and volumetric changes.

No damage due to joint or bearing movement shall be permitted at SLS and no irreparable damage shall occur at ULS. Joint or bearing movements and loads assumed in the design shall be clearly identified on the plans.

All exposed steel components of joints and bearings shall be protected against corrosion. The details and specifications of the corrosion protection system shall be approved by the owner.

In the designing and detailing of deck joints and bearings, the following shall be considered:

a) the properties of the materials in the structure, including the coefficient of thermal expansion, the modulus of elasticity, Poisson’s ratio, elastic shortening, creep, and shrinkage;

b) the effective temperature range of the structure;
c) the sizes of the structural members in contact with the bearings;
d) the method and sequence of construction;
e) the anticipated tilt, settlement, and movement of supports;
f) the construction tolerances;
g) the static and dynamic response of the structure;
h) the interaction of the force effects to which the structure could be subjected, including those due to dead and live loads, wind, earthquake, and earth pressures;
i) the structural restraints; and
j) inspection and maintenance requirements.

In all cases, both short-term and long-term effects shall be considered.

11.4.2 Design requirements

Thermal movements calculated from the extreme temperatures specified in Section 3 and the estimated setting temperature shall be accounted for in the design of the joints and bearings.

The setting of deck joints and bearings shall be based on the effective bridge temperature at the time of installation, which may be assumed to be the mean shade air temperature taken over the previous 48 h for concrete structures and the previous 24 h for steel structures.

The resistance factor, ϕ, applied to the capacity of a joint or a bearing assembly shall be in accordance with the applicable Section of this Code.

11.5 Deck joints

11.5.1 General requirements

11.5.1.1 Functional requirements

Deck joints shall be designed and detailed to accommodate the translation and rotation of the structure at the joint.

Deck joints shall be designed to provide for the unhindered passage of traffic across the joints without impairing the riding characteristics of the roadway or damaging vehicles.

The type of joint and size of surface gap shall accommodate the safe passage of motorcycles, bicycles, and pedestrians, as necessary. In particular, where bicycle paths and pedestrian walkways are designed as part of the roadway, the gap opening shall be controlled by cover plates or bridging plates so that the maximum opening does not exceed 25 mm.

Joint armour, armour connections, and anchors shall be detailed to avoid damage from snowplows. Sealing elements shall be located at least 10 mm below the riding surface.

The deck joint components in the vertical faces of curbs, parapet walls, or barrier walls exposed to the action of snowplows or other maintenance equipment shall be recessed at least 20 mm.

Where cover plates are used over the sidewalk and curb areas, they shall be installed with the free end pointing in the direction of the adjacent traffic. Protection against snowplow action shall be considered for cover plate installations in driving lanes over roadway areas.

Deck joints shall be detailed to prevent damage to components of the structure (e.g., the deck, bearings, piers, and abutments) from water, de-icing chemicals, and roadway debris.

Longitudinal deck joints shall be provided, but only where necessary, to accommodate the effects of differential movements between adjacent longitudinal segments of the bridge.

Sealed joints shall remain watertight at SLS.

The joint shall be accessible for inspection and maintenance. In addition, components such as the seals as well as the bearings and springs in modular joints shall be replaceable.

11.5.1.2 Design loads

A joint shall be designed to withstand combinations of wheel and horizontal loads with appropriate load factors and dynamic load allowance.

A single wheel load, in accordance with the requirements of Section 3, shall be used to calculate the maximum force effects in the various components of the joint. Any portion of the wheel load over the joint gap shall be applied at only one edge of the gap. Load dispersion at an angle not exceeding 45° shall be permitted within the joint components where justified by the continuity and rigidity of the joint.

For armouring of all joints including modular joints, a horizontal live load of 60 kN per metre length of the joint shall be applied at the road surface, in combination with the forces that result from the movement of the joint, to produce maximum force effects. Loads for other portions of modular joints shall be as specified in Section 3.

11.5.1.3 Structural requirements

Deck joints shall satisfy the requirements of SLS, FLS, and ULS. The joints and their supports shall be designed to withstand factored load effects over the range of movements, as specified in Section 3.

A joint shall be detailed in such a way that any damage to the joint occurring at ULS is repairable while the bridge remains in service.

In calculating the movement at a joint in a bridge superstructure, the length taken as affecting the movement shall be the distance between the reference point and the zero movement point. For curved superstructures, this length shall be taken along the chord. In calculating the location of the zero movement point, the stiffnesses of the supporting systems of the bridge shall be taken into account.

All joints, including those in curbs, parapets, and barrier walls, shall be positioned and oriented to accommodate total movement with reference to the zero movement point.

The moving components of the joint shall be designed to work in concert with the bearings to avoid binding of the joints and the resulting adverse force effects on the bearings and structural elements.

11.5.1.4 Materials

The surface of the joint exposed to pedestrian traffic shall be skid resistant. All materials in the joint shall be durable and resistant to abrasion, corrosion, and damage from traffic and snowplows.

Materials directly in contact with each other shall be electrically, thermally, and chemically compatible; where incompatibility exists, materials should be insulated from each other.

All fasteners for joints exposed to de-icing chemicals shall be fully protected against corrosion.

11.5.1.5 Maintenance

Deck joints shall be designed to operate with a minimum of maintenance. They shall be replaceable (except for elements permanently attached to the structure) and accessible for inspection and maintenance.

Sufficient space for access to the joints from below the deck shall be provided by proper detailing of adjacent components. For the deck joints of large bridges not directly accessible from the ground, access, e.g., inspection hatches, ladders, platforms, and catwalks, shall be provided where practicable.

Joint armour, armour connections, and anchors shall be detailed to avoid damage from snowplows.

The top surface of piers and abutments under deck joints shall be sloped to prevent the accumulation of water and debris.

11.5.2 Selection

11.5.2.1 Number of joints

The number of deck joints in a structure shall be kept to a minimum. Preference shall be given to continuous floor systems and superstructures. To permit expansion when required, a joint shall be provided on the approach slabs of integral abutment bridges.

The deck and supporting structural system shall be designed to minimize and withstand the forces generated by restraint to movements, unless deck joints and bearings are provided to facilitate the movements.

11.5.2.2 Placement

The longitudinal movement of deck joint elements shall be consistent with that provided by the bearings at that location.

11.5.2.3 Types of deck joints

A sealed deck joint shall be provided where the joint is located directly above structural members and bearings that would be adversely affected by water and debris accumulation, and where de-icing chemicals are used. It shall seal the surface of the deck, including curbs, sidewalks, medians, and, where necessary, parapet or barrier walls. The joint shall prevent the accumulation of water and debris that could restrict its operation.

An open deck joint shall be used only if drainage away from the bearings can be ensured year round. Where de-icing chemicals are used, the drainage system shall be adequately protected against corrosion.

11.5.3 Design

11.5.3.1 Bridge deck movements

11.5.3.1.1 Sealed deck joint

The width of a roadway surface gap in a transverse deck joint, measured normal to the joint at SLS movement, shall not exceed 100 mm for a joint with a single opening and 80 mm for any gap in a joint with multiple openings.

Gaps in a deck joint with multiple openings shall remain equal and parallel to each other.

When the skew angle of the deck joint exceeds 20°, only those deck joints whose movement capacity has been demonstrated by the manufacturer may be used.

11.5.3.1.2 Open deck joint

Open deck joints shall only be used when approved by the owner. The width of the roadway surface gap in an open transverse deck joint shall be not less than 25 mm or greater than 60 mm at SLS movements.

11.5.3.2 Components

11.5.3.2.1 Bridging plates

Joint bridging plates shall be designed as cantilevers capable of supporting wheel loads and accommodating bridge articulation.

Where longitudinal movement might cause binding of the bridging plates, the movement plane of the bearings shall match the movement plane of the joint.

11.5.3.2.2 Armour

The armour shall be detailed to eliminate the formation of air voids during placing of adjacent concrete.

The armour shall be provided with studs with a minimum diameter of 20 mm or snowplow plates with a minimum thickness of 10 mm. The length of the studs or snow plow plates shall be not less than 200 mm. The spacing shall be not more than 200 mm for studs and not more than 300 mm for snow plow plates.

11.5.3.2.3 Joint anchorage

The joint anchorage shall be connected directly to the structural steel supports or engaged with the reinforced concrete or the elastomeric concrete substrate through bonding. Joint anchorage within elastomeric concrete shall require approval by the owner

Joint anchorage on each side of the deck joint assembly shall satisfy the following minimum requirements:

a) the factored resistance of the joint anchorage shall be not less than 600 kN/m for any meter length in any direction;
b) the spacing of the joint anchors shall not exceed 250 mm; and
c) where the deck joint assembly is attached by reinforcing bars, studs, or bolts cast into concrete, the total cross-sectional area of the steel anchors shall be not less than 1600 mm^2/m.

11.5.3.2.4 Bolts

All anchor bolts for bridging plates, joint seals, and joint anchors shall be high-strength bolts fully tensioned as specified in Clause A10.1.6.7. Cast-in-place anchors shall be used only in new concrete. Expansion anchors and countersunk anchor bolts shall not be permitted on any joint connection unless approved by the owner.

11.5.4 Fabrication

Deck joint components shall be of sufficient thickness to stiffen the assembly and prevent distortion due to welding and galvanizing.

To ensure proper fit and function, joint components shall be fully assembled in the shop. If possible, the joint and seal shall be shipped to the job site fully assembled; otherwise, permanent seals shall not be placed before joint armouring and anchorage installation have been completed.

11.5.5 Installation

The plans shall include, in tabular form, the installation gap openings throughout the designated installation temperature range.

Construction joints and blockouts shall be used where practicable to permit the placement and adjustment of the joint after the backfill and major components have been placed.

Where staged construction is used, joint design shall include details for transverse field splices. Splices shall be designed to provide satisfactory fatigue life. Where practicable, splices should be located away from the wheel paths and the gutter areas.

Seals shall be installed in one continuous piece.

11.5.6 Joint seals

All seals for joints shall accommodate required movements at SLS and ULS and be designed to remain watertight and prevent the accumulation of water and debris that could restrict the operation of the joints.

Elastomeric glands or membranes shall be placed in such a way that they remain below the roadway surface at the minimum gap opening in accordance with Clause 11.5.1.1.

11.5.7 Sealed joint drainage

Where practicable, drainage accumulated in the sealed joint shall not be discharged on any portion of the structure.

11.5.8 Open joint drainage

In the design of open joints, the discharge of water and debris shall be diverted from the bearing areas and structural elements by a suitable system, e.g., a trough-collector-downspout system. Troughs shall have a minimum of 10% slope to facilitate drainage.

11.5.9 Volume control joint

A volume control joint shall be designed to transfer all static and dynamic wheel loads to the structure.

A volume control joint shall be used only when the maximum joint gap below the seal is less than 20 mm.

The width of the joint binder shall be at least ten times the maximum gap of the joint below the seal. The sealant shall have sufficient bond strength with all surfaces with which it is in contact.

The use of proprietary volume control joints shall require approval by the owner.

11.6 Bridge bearings

11.6.1 General

11.6.1.1 Design considerations

Bearings shall support and transfer all loads while accommodating translations and rotations in the structure.

Uplift-restraint devices shall not restrict the function of a bearing. The uplift-restraint device shall not limit the rotation capacity nor the displacement of the bearings at any load combination.

The bearing seats of the structure shall be detailed to ensure complete contact with the bearing under all load combinations.

The following maximum and minimum loads and movements corresponding to the critical combinations at SLS and ULS shall be shown on the plans:

a) dead load;
b) total load;
c) lateral loads;
d) rotations; and
e) translations.

Any other requirements that need to be satisfied shall be shown on the plans, including the fabrication and construction tolerances assumed in the design.

For bearings other than elastomeric bearings, the design-bearing rotation, θ_u, including the fabrication and construction tolerances, shall be taken as the sum of the rotations due to ULS loads and tolerances in fabrication and installation, plus 0.02 radians.

Bearings shall be designed to operate with minimal maintenance. They shall be accessible for inspection and maintenance and replaceable without damage to the structure or removal of anchorages permanently attached to the structure. To facilitate their placement, bearings shall be detailed so that they can be removed by jacking the superstructure by an amount not exceeding the vertical relaxation recovery of the elastomeric material within the bearing plus 5 mm. Bearings shall not be recessed into plates, or welded to plates, that are permanently attached to the structure.

For bearings with sliding elements, the plans shall include a table of the required settings throughout the probable temperature range at the time of installation.

Plans shall specify the bearing translations in each of the two orthogonal directions for movements at ultimate limits states. At ULS 4, the translation requirements for combined seismic and thermal movements shall be in accordance with Clause 4.10.6.

Bearings shall be plant assembled so that their assembly remains intact during transportation and installation. The temporary connections shall be removed only after the bearings have been installed with permanent connections. The bearings shall be set to the specified plane within a tolerance of ± 0.0035 radians in any direction. The top of a bearing shall be set at the design elevation within specified tolerances.

Grout bedding for bearings used for surface levelling shall be approved by the owner. The grout shall be inert and free from shrinkage and staining. Grout bedding shall not be used with elastomeric bearings unless steel masonry plates are also used.

The bearing design shall take account of induced moments and the horizontal forces induced by sliding friction, rolling friction, or deformation of a flexible element in the bearing.

The requirements of Section 2 shall apply in addition to the content of this Section.

11.6.1.2 Selection of bearing type

The type of bearing specified on the plans shall be capable of meeting the loading and movement specified on the plans.

All components connected to the bearings shall be designed to resist the forces induced by the bearing's resistance to rotation.

Note: *All bearings provide some restraint to rotation around the horizontal axis. The magnitude of the restraint is a function of the bearing type.*

11.6.1.3 Horizontal loads

Fixed and guided bearings shall be capable of resisting lateral loads in the restrained direction as required by the design, but not less than the following:

a) 10% of the vertical load capacity for bearings with a total vertical load capacity of up to 5000 kN at SLS and at ULS; and
b) 500 kN, plus 5% of the vertical load exceeding 5000 kN, for bearings with a total vertical load capacity exceeding 5000 kN at SLS and at ULS.

11.6.1.4 Bolted connection

Bolted connection between the steel plates should meet the requirements of Clause 10.18.2.3.3. For bearings that are subjected to uplift force, the bolted connection shall meet the requirements of Clauses 10.18.2.2 and 10.18.2.4. Additionally, for bearings that are subject to uplift at SLS, the bolts shall be pre-tensioned in accordance with Clause A10.1.6.

If the mating surface between bolted steel plates are machined, and if the bearing is installed within 0.1 radians of the horizontal plane, the requirements of Clause 10.18.4.5 do not apply.

11.6.1.5 Materials

The steel components of bearings shall be made of carbon steel that complies with CSA G40.20/G40.21 Grade 260W, 300W, 350W, or 350A; stainless steel that complies with ASTM A240/A240M; or other materials approved by the owner.

11.6.2 Metal back, roller, and spherical bearings

11.6.2.1 General

The rotation axis of rocker and roller bearings shall be aligned with the axis of the largest expected rotation of the supported member. Steps shall be taken to ensure that the bearing alignment does not

