Bearings and Expansion Joints: selection criteria based on span and superstructure type; expansion joint types, design, detailing, and installation

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Abstract-This paper investigates the selection, design, detailing, and installation of two essential bridge components: bearings and expansion joints. The focus is on how span length and superstructure type (material, continuity, support conditions) influence bearing choice; and how expansion joint types are selected based on movement demands, structural type, durability, and maintenance. The paper also presents design-calculation methods, detailing practices, installation considerations, and the interaction between bearings and joints. Illustrative discussion draws from guidelines and documented experience to provide recommendations for best practice and future research.

Keywords-Bridge bearings, expansion joints, span length, superstructure type, movement accommodation, detailing, installation, durability.

I. INTRODUCTION

Bridges must safely transfer vertical loads from the superstructure to the substructure while accommodating various movements and rotations induced by temperature variation, creep/shrinkage, elastic shortening (in prestressed concrete), live-load deflections, wind, seismic action, and foundation settlement. Bearings and expansion joints are the key components that enable this articulation.

Bearings serve as the interface between the superstructure and substructure, transmitting loads and allowing controlled translations and rotations. Expansion joints provide the gap or device that allows adjacent parts of the structure to move relative to each other, or relative to abutments, without inducing undue internal stresses or distress.

The performance of bearings and expansion joints is critical for serviceability, durability, ride quality, and maintenance. Poor selection or detailing may lead to premature failure, water ingress, corrosion of the substructure, a rough riding surface, and higher lifecycle cost.

This paper addresses: (1) selection criteria for bearings based on span length and superstructure type; (2) types of expansion joints and their selection; (3) design and detailing of expansion joints; (4) installation and practical considerations; and (5) the interaction between bearings and expansion joints and recommended best practices.

II. BEARINGS: SELECTION CRITERIA BASED ON SPAN AND SUPERSTRUCTURE TYPE

2.1 Function and Bearing Types

Bearings are structural devices that transmit loads (vertical, horizontal) from the bridge superstructure to the substructure, and permit relative movement (translation and rotation) between these structural components.

Common bearing types include:

- Elastomeric bearings (plain rubber pads or steel-reinforced)
- Sliding bearings (typically PTFE or steel/PTFE combination)
- Pot bearings (for large vertical loads and rotations)
- Spherical bearings
- Seismic isolation bearings (for large displacement demands)

Each type offers different capacities for movement, rotation, load, maintenance requirement, cost, and durability.

2.2 Selection Criteria: Span Length and Superstructure Type

The choice of bearing is strongly influenced by the span length and the superstructure type (material, geometry, continuity, support conditions). The following factors apply:

Span length: Longer spans usually imply greater thermal movements, greater elastic deformations (deflections/rotations), and possibly larger live-load induced displacements. Accordingly, bearings must accommodate greater translations and rotations. For short spans, simpler bearing types (e.g., plain elastomeric pads) often suffice. For longer spans, sliding or pot bearings may be required. For example, a guideline notes that “for a given bridge structure the bearing type must be selected based on load, translation, and rotation demands.”

Superstructure type:

- Concrete (reinforced, pre/stressed) superstructures exhibit shrinkage, creep, elastic shortening, and sometimes integral abutment behavior. These phenomena contribute to movement demands on bearings. For example, for concrete bridges, the guidelines recommend semi-integral construction for certain lengths (which influences bearing choice).
- Steel superstructures typically see larger thermal expansion/contraction and may need bearings that allow larger translations. The material stiffness and deflections differ from concrete. A manual shows steel bridges may have greater translation capacity requirements ($\pm 100 \text{ mm}$ or more) compared to elastomeric pads.

Support condition & continuity: Whether the superstructure is simply supported, continuous, integral with abutments, or multi-span influences bearing design. For continuous spans, rotations at bearings due to deflection and differential settlement must be accommodated; for integral abutment bridges, the need for translational bearings may be reduced or eliminated.

Movement and load capacity: The bearing must meet both vertical load capacity and horizontal/rotational movement demands. For example, the document shows design example values: an elastomeric bearing pad with a translation of $\pm 6 \text{ mm}$ versus a PTFE sliding surface with $\pm 200 \text{ mm}$ translation.

Maintenance, accessibility, durability: The bearing location is typically exposed to moisture, debris, and traffic spray; thus, bearing selection must include considerations for inspection access, ease of replacement, and longevity.

Detailed guidelines often present tables of recommended bearing types versus movement/rotation ranges; e.g., for low translation ($< \pm 50 \text{ mm}$), elastomeric; for larger translation, sliding or pot bearings.

2.3 Detailing and Interface with Expansion Joint

Bearings must be detailed and installed in a way that supports the adjacent expansion joint design. Some key considerations:

- The bearing seat and anchor must provide uniform load transmission and avoid excessive edge bearing or localized stresses.
- The rotational and translational capacity of the bearing should be consistent with the movement accommodated by the expansion joint. If bearings restrict movement, it will force more demand on joints (or cause structural distress).
- The bearing location influences where expansion joints are placed (e.g., at abutments or at internal spans), and the joint gap must align with the bearing layout and movement pattern.
- During installation, adjust for tolerances, ensure proper seating, and provide lifting anchors for future replacement (bearing replacement should be considered at the design stage).

2.4 Summary: Criteria Table (Suggested)

(This section confirms the idea for a table)

III. EXPANSION JOINTS: TYPES, SELECTION, DESIGN & DETAILING

3.1 Introduction to Expansion Joints

Expansion joints in bridges are structural components placed at the ends of spans or between superstructure segments (or between the superstructure and abutment) that allow relative movement while maintaining riding surface continuity, structural integrity, and waterproofing. They are one of the most maintenance-sensitive elements of bridges.

Typical movements to be accommodated include thermal expansion/contraction, shrinkage/creep, elastic shortening, live-load induced deformations, seismic displacements, wind thrusts, and foundation settlement.

Good expansion joint design achieves: minimal water and debris ingress into the structure, good ride smoothness, durability under traffic and environmental loading, and minimal differential settlement across the joint gap.

3.2 Types of Expansion Joints and Movement Ranges

Various joint types exist, each suited to a range of movement and structural demand:

According to the Washington State Department of Transportation (WSDOT) manual:

- Small-movement range joints (for movements typically $< \sim 50 \text{mm}$): compression seals, poured sealants, asphaltic plug joints, pre-formed foam, etc.
- Medium-movement range joints (movements up to $\sim 100-200 \text{ mm}$): strip seal joints, steel sliding plate joints, bolt-down panel joints.
- Large-movement range joints (movements $> \sim 200 \text{ mm}$, sometimes $300-600 \text{ mm}$ or more): steel finger joints, modular expansion joints.

Other classifications (from literature) include: modular expansion joint systems (kits) for high-movement bridges (e.g., long-span, seismic); sealed compression joint systems for minor movements; transitional joint systems for intermediate movements.

3.3 Selection Criteria for Expansion Joints

Selecting the appropriate expansion joint involves the following criteria:

- Magnitude of movement: The total expected movement (longitudinal expansion + contraction + other movement types) must be computed before selecting a joint. The joint must have a capacity greater than the expected movement, with margin.
- Direction and type of movements: Not only longitudinal movement, but lateral, vertical jumps (due to settlement or deflection), and rotational changes must be accommodated. Some joints are better suited to translations only; others include vertical/rotational capacity.
- Superstructure type and span: The superstructure behavior influences movement. For example, long-span continuous steel bridges may have large translations and rotations versus short simply supported concrete spans. The joint selection must match that.
- Traffic loading and service conditions: Heavy traffic, dynamic loads, heavy trucks, and high speeds impose additional fatigue and seal-wear demands. Maintenance access may be more difficult; the joint type must consider durability and ease of replacement.
- Waterproofing and debris prevention: The joint must block water and salt ingress to the substructure, which can accelerate corrosion or reduce bearing life.
- Maintenance, lifespan, cost: Joint systems differ greatly in cost and maintenance demand. Some are easier/cheaper for replacement; some require major work. The entire life-cycle cost must be factored.
- Installation and constructability constraints: Availability of space for blockouts, timing of deck pour, tolerances, and manufacturing lead-time for modular systems.
- Seismic/displacement demands (for seismic regions): In earthquake zones, expansion joints must accommodate seismic displacements; if bearings provide large translations (e.g., seismic isolation), joints must match those.

3.4 Design & Detailing of Expansion Joints

3.4.1 Movement Calculation

Key steps include:

1. Thermal movement: $\Delta L = \alpha \times L \times \Delta T$. For steel bridges, ΔT may be larger; concrete structures include the temperature range, plus shrinkage and creep.
2. Shrinkage/creep/elastic shortening: Especially for concrete superstructures; many guidelines provide strain values or formulae (e.g., WSDOT uses $\Delta L_{\text{shrink}} = \beta \cdot \mu \cdot L_{\text{trib}}$) for the shrinkage effect.
3. Live load movement: Vertical deflection and movement might cause relative displacement across the joint gap; rotational movement may

translate to gap opening. The engineer must estimate or model this.
4. Settlement/torsion/rotations: Especially in long bridges or skewed abutments.
5. Seismic/transverse/wind/bridge skew: If applicable.
6. The total required movement capacity is then derived, and the joint type selected accordingly (with margin). Some classifications adjust for extreme events (e.g., seismic movement may exceed normal movement).

3.4.2 Detailing
Key detailing aspects include:
- Blockout in deck or approach slab: The joint device must anchor to the structure; provision for embed plates, anchor bolts, and reinforcement around the joint.
- Drainage and waterproofing: The joint gap must be sealed or have drainage to prevent infiltration of water/salts to the deck underside and bearings. Some designs incorporate seals, elastomeric strips, or compressible fillers.
- Approach slab and pavement interface: Smooth transition into the joint to maintain ride quality; kerb details, level tolerance, and closure strip. The joint should not create a bump or crack hazard.
- Anchor and fixings: Especially for modular expansion joints: center beams, crossbeams, edge beams; anchoring plates, bolts, and welding where required. Example: the European Assessment Document for modular joints outlines anchorage, fixings, and corrosion protection.
- Seal and wear elements: Some joints include replaceable seals, sliding surfaces, or metal twin-plates. Selection of materials (PTFE, stainless steel, neoprene) is critical for performance.
- Access/maintenance provision: Designing for future replacement of wear components, provision of lifting anchors, and inspection space. Note, for bearings we earlier saw “allow lifting jacks, provide space for replacement.”
- Coordination with bearings: The joint detail must align with the bearing location, superstructure end dimensions, gap movement, and substructure settlement expectation.

3.5 Installation & Construction Considerations
During installation and construction, the following matters warrant attention:
- Timing relative to deck pour: Many joints are installed after deck placement and after shrinkage has partly occurred; for example, WSDOT notes joints must be installed 30–60 days after deck placement so that subsequent shrinkage is left for the joint to accommodate.
- Tolerances and alignment: Modular joints in particular require very accurate alignment of center beams and anchor plates; incorrect alignment can reduce lifespan, create noise, or lead to ride quality issues.
- Block-out preparation: Ensure the correct geometry of the recess, reinforcement around the joint, and proper embedment plates and anchors as per the detail.
- Monitoring during installation: Ensuring that the gap is set correctly for expected movements, that seals are properly compressed, sliding surfaces are aligned, and drainage paths are clear.
- Traffic management: On busy highways, the elimination of long closures is important; for some joint replacement, modular systems may allow partial lane closure only. The maintenance strategy should influence selection.
- Quality control: Material certificates, fabrication tolerances, welding inspection, anchor bolt tensioning, and corrosion protection. For modular joints, the European standard requires testing for fatigue, wear, watertightness, etc.
- Inspection and maintenance access: During installation, provide access for the future replacement of seals/sliding parts, lifting for bearing replacement, and drainage cleaning, etc.

IV. INTERACTION BETWEEN BEARINGS & EXPANSION JOINTS

The design of bearings and expansion joints cannot be done in isolation: they are interdependent. Key points:
- The bearing must allow the movement that the superstructure imposes; the expansion joint must accommodate the movement that remains after the bearings and substructure allowances. If the bearings restrict movement, the joint will be overstressed; conversely, if the joint capacity is

insufficient, either stresses will accumulate in the structure or bearing loads will increase.

- For integral or semi-integral bridges (few or no expansion joints), the bearing design must permit movement into the substructure/backfill; if bearings are fixed rigidly, the joint gap may see larger movement. The WSDOT manual notes that for certain spans, semi-integral construction is preferred to avoid joints altogether.
- For continuous superstructures, rotations at bearings (due to deflection) plus translational movement mean the joint design must allow not just pure translation but also angular offsets, vertical jumps, and possibly torsional offsets depending on the skew.
- In seismic zones, if seismic isolation bearings are used (which allow large displacements), then the expansion joint system must be sized for those large displacements, otherwise the isolation benefit is lost, and damage may migrate to bearings or the substructure.
- Maintenance strategy: If bearings require periodic replacement, the joint design should allow bearing replacement without complete dismantling of the joint. Similarly, joint replacement should not require bearing replacement unless designed for that.
- Cost-life-cycle optimization: The bearing and joint system should be designed together for minimal maintenance cost, durability, and smooth ride quality. Costly, frequent replacement of joints or bearings undermines the bridge performance.

V. CASE STUDIES / RESEARCH FINDINGS

Various investigations document performance, maintenance issues, and selection outcomes:

- The TRB scan report “Experiences in the Performance of Bridge Bearings and Expansion Joints” provides empirical data on bearing and joint failures, maintenance frequency, common distress mechanisms, and performance trends.
- A study “Evaluation and Policy for Bridge Deck Expansion Joints” by Chang (2001) evaluated five joint types and found certain types (strip seal, etc.) performed better in practice over time.
- A paper “Selection of Bridge Expansion Joints” provides classification of joint types, movement demands, issues in seismic regions, and replacement considerations for existing bridges.
- The Indian document “Bridge Bearings and Expansion Joints” (IAHE) provides criteria, design examples, distress types, and maintenance observations for Indian bridges.

From these sources, typical observations include:

- Expansion joints are often the “weak link” in bridge decks: ingress of water/salts through the joint leads to corrosion of the substructure and bearings, accelerating deterioration.
- Bearings often fail due to excessive movement/rotation beyond design, misalignment, or lack of maintenance access.
- Bridges with integral construction (no joints) show lower maintenance cost but require well-designed bearings/backfill conditions to accommodate movement.

VI. RECOMMENDATIONS / BEST PRACTICES

Based on the above, the following best practices are recommended:

- For short spans (say $< 40-60 \text{m}$) and simple superstructure types (e.g., single span concrete girder), consider integral or semi-integral construction (reducing or eliminating expansion joints) to reduce maintenance.
- For medium to large spans or where the superstructure material is steel (with large thermal movements) or where seismic displacement is significant, perform detailed movement analysis (thermal, shrinkage, creep, live-load deflection, settlement) to compute joint movement capacity and bearing movement/rotation demands.
- Select bearings with sufficient translational and rotational capacity for predicted movements and deflections; consider low-maintenance types if access is difficult.
- At the same time, select expansion joints whose movement capacity covers predicted movement with a safety margin; choose the joint type (small, medium, large movement) based on movement magnitude, traffic conditions, maintenance access, and durability.

- Ensure detailing (blockouts, anchor plates, drainage, approach slabs, seals) is comprehensive and coordinated between bearing layout and joint gap.
- For installation, ensure timing (after deck shrinkage), alignment, tolerances, and quality control of materials and fabrication, and ensure design provision for future inspection and maintenance (lifting points, replaceable components).
- In seismic regions, ensure bearings (especially isolation bearings) and expansion joint systems are designed together: the joint must accommodate the large displacements from bearings.
- Provide access and a strategy for future maintenance and replacement: design for bearing/joint removal and replacement without causing major disruption.
- Monitor performance (inspection cycles, condition assessment) and incorporate life-cycle cost evaluation when selecting systems (initial cost + maintenance cost + replacement cost).
- Document lessons from prior cases (joint leaks, bearing misalignment, early wear) and consider material choices (stainless steel, PTFE, durable seals) and protective measures (waterproofing, corrosion protection) early.

VII. CONCLUSION

Bearings and expansion joints are pivotal to the long-term performance and durability of bridges. Their selection, design, detailing, and installation must be considered in an integrated manner, incorporating span length, superstructure type, movement demands (thermal, shrinkage, live load, seismic), support conditions, and maintenance strategy. By properly analysing the demands (translations, rotations), selecting appropriate types (elastomeric, sliding, pot bearings; small/medium/large movement joints), and ensuring detailed coordination between bearings and joints and good installation practices, bridge designers can substantially reduce maintenance costs, improve riding quality, and extend service life. Further research is warranted in areas such as advanced materials (for sliding bearings and joints), performance monitoring (non-contact assessments of joints), long-span/high-speed rail bridges where movements are extreme, and life-cycle cost optimisation.

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Appendices (Suggested)
Appendix A: Table of recommended bearing types versus span length and superstructure type.
Appendix B: Table of expansion joint types versus movement capacity and typical applications.
Appendix C: Sample calculation of movement (thermal, shrinkage, live load deflection) for a hypothetical bridge.
Appendix D: Detailing sketches (blockout, seal detail, anchorage) for expansion joint installations.
Appendix E: Maintenance schedule table for bearings and expansion joints (inspection intervals, possible distress, replacement triggers)