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BRIDGE EXPANSION JOINTS REPLACEMENT CHALLENGES – A REVIEW

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Abstract- Bridge expansion joints play a critical role in maintaining the structural integrity, functionality, and serviceability of bridges by accommodating movements caused by thermal fluctuations, shrinkage, creep, and dynamic loading. However, due to their exposure to harsh environmental conditions and repeated traffic loads, expansion joints are prone to accelerated deterioration, often necessitating repair or replacement well before other bridge components. The replacement of expansion joints presents a unique set of challenges that extend beyond simple component substitution. These challenges encompass design issues, such as ensuring compatibility with ageing structures, recalculating movement ranges under modern codes, and selecting appropriate joint types, as well as construction challenges including unexpected services, poor bridge deck or abutment conditions, adverse weather impacts, and health and safety risks. This paper provides a comprehensive review of the multifaceted challenges associated with bridge expansion joint replacement, drawing upon current literature, case studies, and practical engineering experience. It highlights the importance of proactive investigation, strategic design decisions, and effective collaboration between designers and contractors to mitigate risks and ensure durable, cost-effective solutions. By addressing both design and construction aspects holistically, this review aims to support practitioners in developing resilient maintenance strategies for bridge infrastructure, ultimately contributing to improved asset longevity and reduced life-cycle costs. The review also identifies a critical gap in knowledge transfer practices and calls for the development of industry-wide mechanisms to capture and share field-level insights from replacement projects.

Keywords- Expansion Joints, Design Challenges, Construction Challenges, Joint Replacement, Structural Durability

1 Introduction

Bridge expansion joints are essential elements of bridge structures, allowing for controlled movement between bridge spans and adjacent structures. They accommodate thermal expansion and contraction, shrinkage, creep, live load deflections, and, where relevant, seismic movements. By doing so, they help prevent unwanted stresses, cracking, and other structural damage to bridge superstructures [1], [2]. However, expansion joints are highly vulnerable to deterioration due to their exposure to repeated dynamic loads, harsh environmental conditions, and the ingress of water and de-icing salts. These factors contribute to wear, fatigue, corrosion, and material degradation, leading expansion joints to often become one of the first bridge elements to require repair or replacement [3]. Their performance directly impacts not only structural integrity but also user comfort, traffic safety, and maintenance costs. Frequent replacement or refurbishment of expansion joints throughout a bridge's life cycle is common. Studies such as those by Lima and de Brito [4] and Chang and Lee [5] highlight that poorly functioning joints are major contributors to deck deterioration, particularly when water leakage compromises waterproofing systems. Failure to maintain effective expansion joints can thus lead to rapid escalation of repair needs elsewhere in the bridge, increasing life-cycle costs significantly.

In accordance with CD 357 [6], bridge expansion joints are classified according to their capacity to accommodate structural movements. The principal categories include small movement joints (up to 40 mm), such as buried, flexible plug and nosing joints, which are typically employed on shorter span structures due to their simplicity and cost-effectiveness. Medium movement joints (ranging from 40 mm to 100 mm), including cantilever systems, offer enhanced flexibility and are suitable for moderate span bridges. For applications involving large movements (exceeding 100 mm), modular joints and supported joints are commonly utilised, offering superior performance in terms of movement accommodation and load distribution. The selection of an appropriate joint type is governed by factors such as span length, traffic loading, environmental exposure, and long-term maintenance requirements. Each type presents unique challenges when replacement is required. Modular joints, for example, are complex systems involving multiple support bars and sealing elements, and their replacement often requires substantial interventions into the bridge structure itself [7]. Despite their criticality, a focused body of literature on the replacement challenges of bridge expansion joints remains relatively limited. Existing research has predominantly concentrated on the behaviour and performance of new joint systems [8], the development of new materials and fatigue-resistant designs [9], or the impact of joint failures on the overall health of bridges [10]. Studies specifically analysing the difficulties encountered during joint replacement including: investigations, design compatibility, waterproofing integration, construction logistics, and quality assurance are comparatively rare.

Replacement challenges are complex. On the design side, ensuring compatibility with an ageing structure, recalculating required movement ranges under modern standards, and diagnosing the original cause of failure are complex tasks. Construction challenges can include encountering unexpected conditions such as hidden services, differing verge compositions, widespread deck deterioration, and adverse weather impacts. Moreover, poor site practices, such as insufficient surface preparation or incorrect waterproofing application, can lead to early failure of the new joint if not adequately managed [11]. While these challenges are widely encountered, the insights gained from addressing them are not consistently captured or shared across the industry. Despite the high volume of bridge expansion joint replacements performed globally each year, there remains a lack of structured integration of practical experience into design standards, guidance documents, or academic literature. Much of the decision-making on-site depends on implicit knowledge held by experienced engineers and contractors, which often remains undocumented. As a result, recurring problems, such as inadequate waterproofing integration or overlooked utility conflicts, continue to affect outcomes. This review not only catalogues technical challenges but also underscores the need for improved knowledge-sharing mechanisms to support more consistent and effective practices across future projects and jurisdictions.

2 Discussion of Design Challenges

The replacement of bridge expansion joints represents a technically demanding and multi-faceted engineering challenge. Expansion joints, which allow for controlled movement and mitigate stresses in bridge decks, are critical to the longevity and functionality of bridge structures. Over time, joints become subject to wear, material degradation, or structural damage, necessitating their replacement to maintain serviceability and safety. However, undertaking this task in existing structures introduces a complex set of design challenges (Table 1), which must be addressed systematically to ensure successful outcomes.

Table 1: Key Design Challenges and Solutions

Design Challenges	**Potential Solutions**
Compatibility of New Expansion Joint with Existing Structure	Ensure compatibility with existing structure, recalculate movement ranges
Identification of the Original Cause of Failure	Diagnose failure causes like fatigue, material degradation, and vehicular impact
Refurbishment Versus Replacement	Decide based on condition, age, maintenance history, and cost
Missing As-Built Records	Conduct special inspections or trial holes to gather necessary information
Traffic Management Plan	Use phased construction, temporary joints, or rapid-cure materials to minimise closure times
Achieving Long-Term Durability	Emphasise durability in design specifications, including corrosion-resistant fixings and protective coatings

2.1 Compatibility of New Expansion Joint with Existing Structure

A fundamental design challenge lies in ensuring that the replacement joint is fully compatible with the existing bridge structure. Key factors include accommodating the current joint gap, as well as recalculating the bridge's range of movement based on contemporary design codes. Modern standards, such as the Eurocodes, typically demand greater allowances for thermal, shrinkage, live load and seismic movements than older national codes. This recalculation often reveals that existing expansion joints are not suitable for the bridge's theoretical movements, especially in older structures, necessitating the selection of a joint system with greater movement capacity.

2.2 Identification of the Original Cause of Failure

Accurately diagnosing the cause of existing joint failure is essential to prevent recurrence. Failure mechanisms can include fatigue damage to components, material degradation due to de-icing salts, insufficient movement capacity, poor workmanship, and damage from vehicular impact. In many cases, particularly for resin-anchored joints, deterioration of the underlying concrete is a major contributor to failure.

a) b)

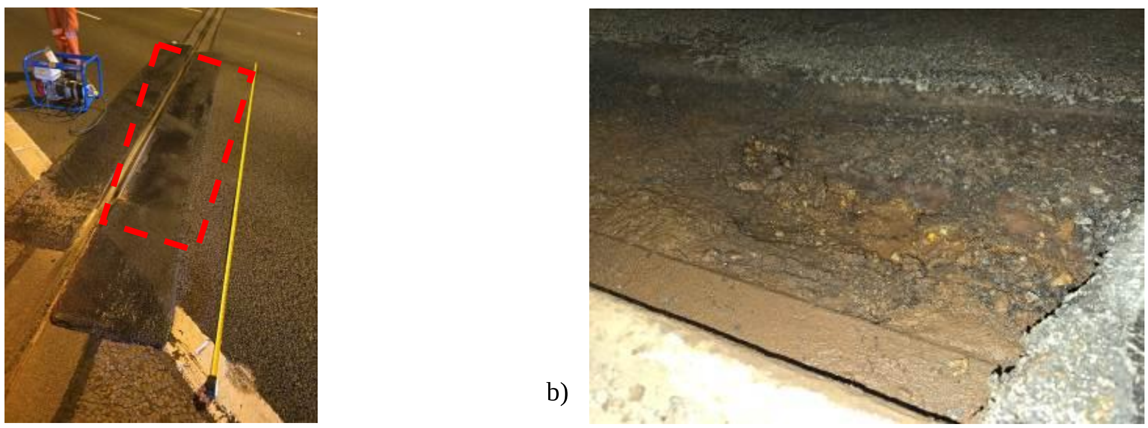


Figure 1: Case study of a bridge with failed expansion joint nosing, a. Photo of the failed temporary repair (highlighted in red box) before excavation, and b. Photo of the bridge deck after excavating expansion joint temporary repair.

Figure 1 shows extensive concrete deterioration at a joint resin location which was temporarily repaired. The poor concrete was visible once the temporary repair was removed. In this case, simply replacing the temporary repair with new joint resin would not be satisfactory. A concrete repair of the bridge deck is required in order to prevent future resin from failing in compression again. In any expansion joint replacement design scheme an investigation should be mandated to understand the reason behind joint failure.

2.3 Refurbishment Versus Replacement

A strategic decision often arises: whether to refurbish the existing joint or to pursue full replacement. Refurbishment can offer significant advantages, including reduced project duration, lower material and labour costs, and minimal disruption to traffic. However, refurbishment is only feasible where the residual life of critical components remains acceptable.
A decision framework should be adopted, based on key factors such as:

1. Condition grading of existing components
2. Age and maintenance history of the joint
3. Predicted future loading and movement demands
4. Cost comparison over the remaining service life

For joints approaching the end of their design life or suffering systemic failures, full replacement is typically more prudent.

2.4 Missing As-Built Records

A major obstacle in bridge expansion joint replacement projects is the frequent lack of as-built drawings, particularly for older structures. Without accurate records, critical parameters such as dimensions and type of present expansion joint system may be unknown. For exposed joints it may be necessary to instruct for a Special Inspection specifically for the expansion joints to collect information required for the design of new expansion joints.
This special inspection may include:

1 Precise measurement of joint gaps at various temperatures
2 Survey of joint profile dimensions
3 Photographic and video documentation
4 Noting visible signs of distress, cracking, or leakage

In the case of buried joints, the recommended solution is to instruct the Contractor to carry out trial holes. These should be performed at anticipated joint locations, allowing direct observation and measurement. Information obtained may include deck and abutment concrete condition, joint gap width, existing waterproofing type and condition, depth of paving.

2.5 Traffic Management Plan

Replacing bridge joints often requires partial or full lane closures, presenting significant challenges for traffic management, particularly on heavily trafficked routes. The design must consider phased construction approaches, temporary joints, or the use of rapid-cure materials to minimise closure times. Designs may incorporate sequencing that enables half-width construction to maintain one open lane wherever possible. Traffic impact assessments should be prepared early in the project, and liaison with highway authorities is essential to agree acceptable working windows and potential diversions.

2.6 Long-Term Durability

Designers should aim for solutions that maximise the life-cycle performance of the replacement joint. Design specifications should emphasise durability, including:
1 Use of corrosion-resistant fixings (e.g., stainless steel or hot-dip galvanised components)
2 Protective coatings for anchorage systems
3 Drainage details that prevent ponding water and freeze damage
4 Clarification of recommended maintenance procedures

Specifications should also require certification of joints e.g. CE Marking, and site quality control should include measuring and testing of installed components, such as torque testing of anchor bolts and water tightness checks.

3 Discussion of Construction Challenges

The construction phase of bridge expansion joint replacement is often fraught with practical difficulties, many of which arise due to the complexities and uncertainties inherent in working with existing structures. Despite detailed design preparations, the actual conditions encountered on site can differ significantly from expectations, leading to risks of delay, cost overrun, and quality compromises. A systematic discussion of common construction challenges (Figure 2), alongside proposed mitigation measures, is critical for improving project outcomes and ensuring durable joint installations.

Challenge	Potential solutions
Discovery of Unexpected Services	1 Conduct detailed utility surveys and trial holes to identify buried services early 2 Plan service diversions or protective measures
Unsuitable Waterproofing Conditions for Buried Joints	1 Carry out exploratory trial holes in advance to assess waterproofing condition 2 Consult Designer for best action if waterproofing is missing or damaged
Variability in Verge or Central Reserve Construction	1 Perform early trial holes or intrusive investigations to identify reinforcement types and concrete condition 2 Allow for extended breakout and reinstatement times in the programme
Widespread Poor Deck Condition	1 Conduct trial holes and surveys well in advance 2 Plan for flexible construction resources
Weather Risk	1 Be prepared to delay or cancel installation works if poor weather is expected
Construction Errors	1 Conduct pre-construction briefings and regular site supervision

Figure 2: Summary of construction challenges and potential solutions.

3.1 Discovery of Unexpected Services

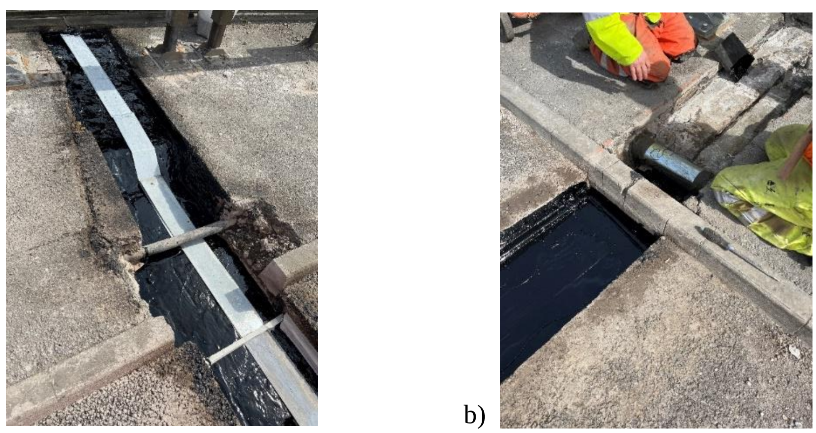
a)  b)

Figure 3: Case study of a bridge with unexpected service duct, a. Unexpected service duct found during asphaltic plug joint replacement construction works, and b. Installation of steel protection to service duct before pouring of hot bituminous material.

One of the most frequent and disruptive challenges during bridge expansion joint replacement is the unanticipated discovery of buried services (Figure 3(a)), particularly in verges or central reservations. Services such as electrical ducts, fibre optic cables, drainage pipes, and even water mains are often found within bridge verges without accurate documentation in the asset records. The presence of such services directly beneath or adjacent to the expansion joint location can severely constrain construction activities, including demolition and reconstruction works. To mitigate this risk, there are various actions that can be undertaken:

1 A detailed utility survey, combining ground-penetrating radar and electromagnetic detection methods, undertaken well in advance of site mobilisation.

2 Targeted trial holes at proposed construction locations can confirm the presence and depth of critical services.

3 It may be possible to protect service ducts such as in Figure 3(b) where protective steel is added around the service duct before pouring of the hot bituminous material of the asphaltic plug joint. However, in many cases such as where there are sensitive services such as fibre electric or gas it is not possible to safely excavated around the service duct to install the new joint without prior approval with the service provider.

4 In many cases it may be required to switch off the service temporarily or re-route the service permanently in order to proceed with an expansion joint replacement. Without planning ahead of time for this, construction works face much larger costs as it would be necessary to return at a later date to complete the expansion joint replacement near the location of service ducts.

Early identification enables the design and construction programmes to be adapted, whether by altering joint positioning, planning service diversions, or implementing protective measures. Failure to undertake sufficient preliminary investigation may result in significant site delays, increased costs, and potential safety hazards.

3.2 Unsuitable Waterproofing Conditions for Buried Joints

Another common and serious issue encountered during construction is the absence or poor condition of existing waterproofing (Figure 4) where new buried joints are to be installed. Effective waterproofing continuity is essential to prevent water ingress into the bridge deck, and poor lapping conditions can critically undermine the integrity of the installation. The recommended strategy is to carry out exploratory trial holes several weeks or months in advance of construction to assess the condition of the deck waterproofing. Where waterproofing is found to be missing, damaged, or unsuitable for lapping, the Designer must be consulted to decide on the best action to deal with the issue. In extreme cases, it may be necessary to re-waterproof part or all of the bridge deck. While such measures involve additional cost and programme implications, they are essential to preserve the long-term serviceability of the bridge structure.

Figure 4: Existing bridge waterproofing left in place to provide lapping with new waterproofing system to be installed at buried joint.

3.3 Variability in Verge or Central Reserve Construction

Unexpected differences in the verge or central reserve construction, particularly regarding reinforcement, present significant challenges during joint replacement. For example, an area expected to be unreinforced concrete may in reality contain heavy reinforcement, significantly increasing the time and effort required to break out and reinstate the area. To mitigate this risk:

1 Conduct early trial holes or intrusive investigations at planned construction locations.
2 Record key details such as reinforcement type, concrete thickness, and substrate condition.
3 Adjust construction methodologies and resource planning based on actual findings.
4 If early investigations are not possible, include allowances in the programme for potential delays and reinforced concrete reinstatement techniques.

Figure 5: Presence of a vehicle restraint system post at expansion joint location.

In Figure 5 it can be seen that there is a vehicle restrain system (VRS) post right at the buried expansion joint location. The Designer must take into account such obstacles in the design solution. In the case of Figure 5, the presence of the VRS post was known and a specialist fencing Contractor removed the post and installed two new posts around the joint. Without prior Designer instruction on this issue, it would not have been possible to remove the VRS post safely (by installing new posts at favourable positions) during the 2 days of works and so the joint would not have been fully replaced. A significant amount of money would need to be expended to visit the site again after the post is moved in order to install the remaining part of the new joint.

3.4 Widespread Poor Deck Condition

A more serious, systemic challenge is encountering widespread poor deck condition during construction, with multiple areas requiring concrete repair. It is not uncommon for older bridge decks to have significant delamination, spalling, or chloride-induced corrosion that only becomes fully apparent once surface materials are removed.
The two-fold mitigation strategy consists of:

1 Conducting trial holes surveys well in advance to determine the likely extent of deterioration.
2 Building conservative assumptions into the construction programme, allowing sufficient float for unexpected concrete repairs.

If extensive repairs are identified as likely, it may be preferable to undertake preliminary deck rehabilitation works ahead of or alongside the joint replacement project. Planning for flexible construction resources, including access to additional labour and materials for repairs, can prevent schedule overruns.

3.5 Weather Risk

Weather conditions, particularly rainfall, pose a serious risk to the installation of most types of joints. Successful bonding of waterproofing membranes and installation of resin-based systems are highly sensitive to moisture levels and temperature. Rain immediately prior to or during installation can compromise adhesion and waterproofing integrity. It is therefore essential that weather forecasts are monitored closely in the days and hours leading up to joint installation. Site management must be prepared to delay or cancel installation works at short notice if inclement weather is expected. Contracts should allow for such flexibility, and protection measures such as temporary covers or shelters should be available where appropriate to shield working areas. A strong culture of quality over programme must be maintained, ensuring that installations are only carried out under suitable environmental conditions.

3.6 Construction Errors

Mistakes during construction, such as cutting away excessive waterproofing during the preparation for buried joint installation, can jeopardise the waterproofing system's effectiveness. The critical lap length between old and new waterproofing layers may be compromised if excessive material is removed. If this occurs, the following steps are recommended:

1 Exposing additional waterproofing in adjacent areas, ensuring that the minimum specified lap length is still achieved.
2 If exposure is not possible or the adjacent waterproofing is in poor condition, the Design team should be consulted immediately to agree an appropriate remediation, which may include local re-waterproofing or doing nothing.

Other construction errors such as installation of defective or incorrect components can be prevented by supervision of construction by a representative of the Designer. Overall, clear and precise method statements, combined with pre-construction briefings and regular site supervision, are key preventative measures to reduce the likelihood of such errors.

4 Conclusions

In summary, the successful replacement of expansion joints in bridge structures relies heavily on the collaborative roles of both Designers and Contractors. Designers play a critical role in ensuring that the specifications and methods align with the requirements of the project. Their expertise is essential in identifying solutions when complications arise, such as compromised waterproofing lap lengths or deteriorated bridge deck condition. Designers must also be proactive in establishing clear and precise method statements that guide Contractors during implementation. Contractors, on the other hand, are responsible for executing the replacement process with precision and adherence to the provided design. Their role includes implementing preventative measures such as rigorous pre-construction briefings and ensuring that site supervision is maintained to reduce the likelihood of errors during construction. Ultimately, the effective collaboration between Designers and Contractors is the cornerstone of successfully replacing bridge expansion joints. By fulfilling their respective roles with diligence and ensuring seamless communication, the longevity and functionality of these critical structural components can be significantly enhanced.

While bridge expansion joint replacements are carried out routinely worldwide, there remains a lack of consolidated industry guidance that synthesises the collective lessons learned from past replacement projects. Despite the wealth of field experience, many replacement efforts continue to face preventable issues due to fragmented knowledge sharing between regions, agencies, and Contractors. Further work is needed to establish unified performance benchmarking, case documentation standards, and feedback loops that translate practical experience into actionable design and construction improvements. Developing such frameworks could significantly enhance the consistency and long-term performance of joint replacement interventions.

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