Performance of Deck Expansion Joints in New Zealand Road Bridges

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S.M. Bruce & D.K. Kirkcaldie
Opus International Consultants
Wellington, New Zealand

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PO Box 2331, Lambton Quay, Wellington, New Zealand
Telephone 64-4-473 0220; Facsimile 64-4-499 0733

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CONTENTS

APPENDICES

Executive Summary

Introduction

Deck joints are a potential source of deterioration and maintenance problems in a bridge structure. The project detailed in this report sought to determine the performance of deck joints in New Zealand road bridges and to establish the suitability of their use and application in comparison to current international best practice. The ultimate aim was to produce guidelines for the use of different generic expansion joints.

An international literature review was carried out and the findings compared to New Zealand practice. Transit New Zealand and selected local authorities provided information on deck joint performance, and deck joint suppliers reported on deck joint types, and supply and installation costs. Bridge deck performance was assessed by inspection of 37 multi-spanned bridges in four separate regions of New Zealand.

Conclusions

Principal findings were:

- Deck joint types in use in New Zealand are similar to those used in the United Kingdom and North America. Buried joints are one exception as they are designed for use with thick surfacing materials which are uncommon in New Zealand.

- The best performing joint type in both New Zealand and the United Kingdom is elastomer in metal runner joints. These should perform satisfactorily for extended periods of time with periodic replacement of seals.

- Some New Zealand road controlling authorities continue to install unsealed joints (e.g. open joints, sliding plate joints) which may lead to deterioration of the bridge substructure caused by water leakage. The preferred option for retrofitting existing unsealed joints when they become unserviceable is to install sealed joints.

- Internationally, there is a clear trend towards making bridges continuous, and also adopting integral abutments where possible, to eliminate deck joints.

- Asphaltic plug joints are becoming more commonly used for retrofitting existing deck joints. Thinner surfacings in New Zealand mean that in some circumstances these joints are installed with reduced dimensions, compared to those originally developed in the United Kingdom. The general performance of these joints was rated as good by road controlling authorities, and the thinner joints were performing adequately, but further work is required to assess the long-term performance of these joints.

- Poured sealant joints are the most common joint type on New Zealand bridges. In general the local authority bridge stock includes a high proportion of small single span bridges with no deck joints. Where they do exist, the joints are commonly low movement, poured sealant joints. The greater proportion of multi-span bridges in the Transit New Zealand bridge stock results in use of a wider variety of deck joints.

- Road controlling authorities rated the overall performance of most deck joint types as acceptable. The exception was that of epoxy-nosed poured sealant joints where the nosings are prone to cracking and debonding.

- According to 1997 work, the total cost of a deck joint is likely to be at least four times the direct cost of supply and installation, with traffic management and road user delay cost being the most significant item. Calculation of whole-of-life costs for joints would provide a basis for joint selection based on long-term performance.

- The experience and knowledge of bridge consultants and road controlling authorities is a contributing factor as to whether a deck joint is selected on the basis of long-term performance or low initial cost. Guidelines for the selection and use of deck joints which are widely available to road controlling authorities and their consultants should improve knowledge and ultimately lead to better long-term deck joint performance.

Recommendations

On the basis of the findings the following recommendations are made:

- With the increasing use of asphaltic plug joints in New Zealand, a more comprehensive understanding is required of the international experience with this type of joint. A comprehensive study is recommended encompassing material specifications, installation practices, and observed performance, to produce rational design guidelines appropriate to New Zealand conditions.

- Consideration should be given to the international trend towards bridges being made continuous, with integral abutments where feasible, and to investigate the implications of adopting this approach for New Zealand bridges.

- UK Department of Transportation Standards BD33/94 and BA26/94 provide the necessary guidelines for the use and selection of deck joints. Therefore an appendix should be included in the Transit New Zealand Bridge Manual which refer to the UK DoT Standards, and incorporate Reference Notes that relate these Standards to New Zealand conditions. Guidelines to developing these Notes are outlined in the report.

- Joint selection should be based on long-term performance and not initial cost. Whole-of-life cost calculations should be used to assist this process.

Abstract

Deck joints are a potential source of deterioration and maintenance problems in a bridge structure and have been identified as the most common maintenance problem in New Zealand road bridges. The performance of deck joints in New Zealand bridges was assessed by consulting road controlling authorities and by inspection of selected bridge structures. The suitability of use and application of deck joints was determined by comparison to current international best practice.

Deck joint types in use in New Zealand are similar to those used in the United Kingdom and North America. Correct installation of all joint types is critical to their long-term performance. The increasing use of asphaltic plug joints with reduced dimensions in comparison to overseas practice requires further investigation. Consideration should be given to adopting the international trend towards bridges being made continuous.

United Kingdom Department of Transportation Standards provide the necessary guidelines for the use and selection of deck joints. An appendix to the Transit New Zealand Bridge Manual (1994) with appropriate Reference Notes that relate the Standards to New Zealand conditions should be developed.

1. Introduction

Expansion joints are included in concrete decked bridges to eliminate or relieve stresses that would otherwise be introduced by continuity of the structure. These include particularly stresses caused by:

- Thermal expansion and contraction;
- Concrete shrinkage during casting;
- Shortening of elements due to prestressing, both initial and long-term creep shortening;
- Different settlement of supports.

Historically, expansion joints consisted of a simple gap in the deck, or open joint, to accommodate small movements and for larger movements sliding plate or cantilever finger plate joints were used. In most of these systems water and debris simply fell though the joint. To prevent this leakage, current practice favours the use of sealed expansion joints. The most commonly used sealed expansion joint systems are poured sealants, compression seals, asphaltic plug joints, reinforced elastomeric joints, and single elastomeric seal in metal runner joints.

Deck joints are a potential source of deterioration and maintenance problems in a bridge structure. Leaking joints can promote corrosion of underlying structural elements and, in extreme cases, embedded debris can prevent movement of the joint causing structural deterioration of the deck. The performance of bridge deck joints on New Zealand road bridges has been of concern for a number of years and was highlighted by Nicholas (1987) and more recently by Bruce et al. (1999). In the latter work, a survey of both local authorities and Transit New Zealand offices recorded deck joint deterioration as the most common maintenance problem affecting bridges of all ages. Bruce et al. (1999) recommended that the performance of bridge deck joints should be investigated so that shortcomings in their effectiveness and durability can be overcome in future construction.

This report presents the findings of a research project carried out to assess the performance of bridge deck expansion joints in New Zealand road bridges. The specific aims of the research were to:

- Determine the performance of different types of deck joints in New Zealand road bridges;
- Establish the suitability of the use and application of deck joints in New Zealand road bridges and compare this with current international best practice;
- Prepare guidelines for the use of different generic expansion joints on new and existing bridges.

To be of the most practical use, the scope of the research was focused in two key areas. First, the majority of New Zealand bridges incorporating deck joints are composed of relatively short, simply supported, spans requiring deck joints designed with movement capabilities of less than 125 mm. For this reason joints for movements in excess of 125 mm (e.g. modular joints) were excluded from the study. Second, the research is primarily concerned with improving current expansion joint practice rather than examining historical aspects of joint performance. Consequently this work concentrated on evaluating the application and performance of expansion joints in current use.

2. Methods

2.1 Review of International Best Practice

The literature review focused on reports and papers published within the last 20 years that presented recommended practices or summarised studies encompassing the performance of a significant sample of joints. Reports that focused on individual bridge structures were not included. Joint types not in common use in New Zealand because of the use of different road surfacing practices (e.g. buried joints as used in the United Kingdom (UK)) have been excluded. Also excluded from detailed investigation within this literature search have been joints for large movements (e.g. modular expansion joints and cantilever comb or tooth plate type joints).

A search of international literature was carried out based on the Opus TeLIS catalogue and the Australian Engineering and Applied Sciences (of ARRB) CD ROM database, searching under the key words "bridge", "expansion", and "joint". The literature identified emanates almost entirely from the UK and North America. Recognised bridge design codes and other known standards which were considered relevant have been included.

Brief outlines of the scope of the principal documents that were reviewed are included in Appendix 1.

2.2 Evaluation of Current Practice

The evaluation of current practice for use of expansion joints was based initially on surveying road controlling authorities and known expansion joint suppliers. This was then followed up by selective inspection of expansion joints in four regions around New Zealand. The selection and sampling of survey candidates and inspection sites was not statistically based but rather was based on decisions made to maximise the quality of the research outputs. Similarly the expansion joint suppliers surveyed were all those who could be identified when the survey was carried out, but it is possible other suppliers and importers may exist who were not surveyed.

2.2.1 Survey of Road Controlling Authorities

The survey was designed to obtain information from road controlling authorities about the extent of use, and the perceived performance of bridge deck expansion joints. Respondents were asked to estimate the number of expansion joints in their current bridge stock, number of recent installations, the types of expansion joints used and their performance, problems encountered with different expansion joints, and typical service lives. The survey requested information on bridge structures incorporating expansion joints which would be appropriate for on-site inspection.

A copy of the survey that was sent out to the authorities is included in Appendix 2.

Bridges on the New Zealand state highway network are administered by seven Transit New Zealand regional offices, and all these offices were selected as candidates for the survey. There are nine Transit New Zealand bridge management consultants and seven of these responded to the survey.

Thirty of the 75 local authorities were selected as candidates for the survey:

- Eighteen local authorities were selected which administered more than 100 bridges and culverts and were geographically distributed in both the North and South Islands;
- All local authorities from the Lower North Island were selected because they are close to Wellington in the event that site inspection would be required;
- The Auckland City Council was selected because they have a high percentage of multi-span inner-city bridges in their bridge stock.

The 30 local authorities selected were:

- Ashburton District Council
- Auckland City Council
- Banks Peninsula District Council
- Carterton District Council
- Central Otago District Council
- Christchurch City Council
- Far North District Council
- Gisborne District Council
- Hastings District Council
- Horowhenua District Council
- Hurunui District Council
- Hutt City Council
- Kapiti Coast District Council
- Manawatu District Council
- Masterton District Council
- Palmerston North City Council
- Porirua City Council
- Rangitikei District Council
- Rodney District Council
- Ruapehu District Council
- Southland District Council
- South Taranaki District Council
- South Wairarapa District Council
- Tararua District Council
- Tasman District Council
- Thames-Coromandel District Council
- Upper Hutt City Council
- Wanganui District Council
- Wellington City Council
- Westland District Council

Fourteen of the 30 local authorities provided a written response to the survey.

2.2.2 Survey of Deck Joint Suppliers

The survey of deck joint suppliers was designed with two principal aims.

1. To collect appropriate data to allow the whole-of-life costs for each joint type to be estimated. Information was collected on supply costs, installation costs, lane closure times for joint retrofitting, and expected joint service life.

2. To identify the location of joint installations in the last ten years (1990-2000) as possible candidates for on-site inspection.

An assessment of the performance of deck joints in each structure was also requested. A copy of the survey sent to suppliers is included in Appendix 3.

Four joint suppliers were identified and surveyed, namely:

- Construction Techniques Ltd
- Environetics Civil Ltd
- Works Civil Construction Ltd
- Bitumen Supplies Ltd

Suppliers of poured sealant joints were not included in the survey.

Supply, installation and cost information for joints from Bitumen Suppliers Ltd were supplied by Conspec Construction Ltd, Tauranga.

2.2.3 Deck Joint Inspection

Site inspections of deck joints were carried out to give an overview of deck joint performance and the nature of problems affecting different types of joints.

Site inspections were carried out in Wellington, Napier, Christchurch and Dunedin, and concentrated primarily on state highway bridges, although some local authority bridges were also included. Inspections were carried out in May and June 1999 and involved the Transit New Zealand bridge consultant in each of the four regions.

A total of 37 multi-spanned bridges were inspected in the four regions. The principal joint type on 35% of these bridges were asphaltic plug joints, 24% were elastomeric in metal runner joints, 14% were reinforced elastomeric joints, and 14% were compression seals. These joints are the principal types used in current practice for new construction and retrofitting. The principal type of joints on 8% of the bridges inspected were poured sealant joints although they were not a primary focus of the survey. A number of the other joints inspected were fitted as a replacement for poured sealant joints. Of the bridges inspected 5% included sliding plate joints as the principal joint type.

Although the number of bridges inspected (37) is a very small proportion of the total bridge stock, when combined with the survey of road controlling authorities and deck joint suppliers, it was considered to provide a representative view of the performance and of the defects affecting specific joint types throughout New Zealand.

The inspections were carried out by visual assessment from the road side, and the degree of watertightness of all joints was determined by inspecting the substructure of the bridge. The substructure inspection was generally carried out on dry days so actual leakage was not observed, and watertightness was determined by the presence or absence of recent leakage staining.

The joints themselves were assessed for signs of deterioration, which was often specific to the joint type. For example, asphaltic plug joints may show signs of rutting in the wheel tracks and cracking within the joint. Reinforced elastomeric joints can be affected by deterioration of the holding down bolts and seals, and the epoxy nosings in compression seal joints may crack and debond.

3. International Best Practice

3.1 Deck Joint Types

A number of different generic types of deck joints are used internationally. They are generally proprietary items which, for the same generic type, can vary significantly in their performance from one manufacturer to another. In general, however the reviewed literature discussed the use and performance of generic joint types with only a few papers (Bramel et al. 1997, Burke 1989,Barnard & Cunninghame 1997b) distinguishing between manufacturers. The same joint types appear to be in use around the world and in New Zealand for the same kinds of movement.

Within the literature a variety of different terms are used to describe essentially the same generic form of joints. Illustrations of the different generic joint types, extracted from Burke (1989) and UK Department of Transportation (1994b), are presented in Figure 3.1. The following list sets out terms that are essentially equivalent and describes the nature of joints or elements that they relate to:

Nosing, transition strip – the upstanding section above the general surface level of the deck concrete, which confines the deck surfacing, and separates it from the movement joint gap. Materials typically used for nosings are concrete, "elastomeric concrete", and epoxy compounds. The ends of the nosing section will often be armoured, e.g. with steel angle sections.

Buried joint – a joint where the deck surfacing is carried continuously across the top of the joint without interruption.

Sliding plate joint – the gap is bridged by a metal plate, fixed on one side of the gap, and sliding on supporting metalwork on the other side.

Asphaltic plug joint (APJ), asphaltic concrete joint, elastomeric concrete joint – in these joints the primary material forming both the nosing and bridging over the joint is an aggregate, bound with a binder of elastomeric material. This material is commonly a rubberised bitumen with filler material, but may alternatively be composed of a proprietary binder of resin and hardeners filled with materials such as silica sand and lime.

Compression seal joint – this comprises a rubber seal element compressed between the nosings on either side of the gap.

Cellular seal joint – this comprises a rubber seal element retained between the nosings on either side of the gap. The rubber seal is of a cellular form, but its retention in position is not reliant on the seal being under compression.

Reinforced elastomer joint – this joint type has two basic variations: the reinforced elastomeric plank joint with the gap bridged by a reinforced elastomeric plank; and the elastomeric sheet seal with the joint bridged by a thin elastomeric sheet, anchored on either side of the gap by reinforced elastomeric block nosings.

Elastomer in metal runner joint (EMR), single seal joint – these joints comprise metal extrusions fixed to the edge of the nosings, that anchor a rubber membrane seal bridging the gap.

Modular joint – these joints generally comprise multiple rubber seal elements retained by metal runners, with the inner metal runners supported on beam elements spanning the gap beneath the seal elements. This form of joint, designed for large movements, is outside the scope of this investigation.

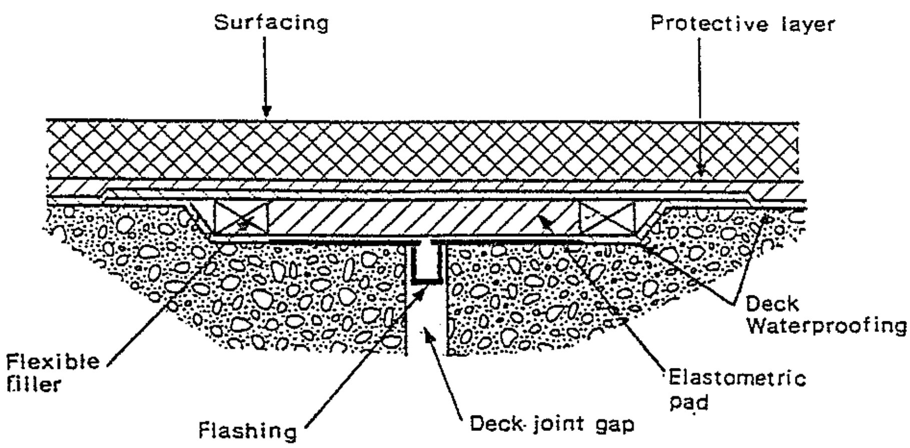
Cantilever finger plate, comb, or tooth joints – these comprise steel-plate or teeth elements cantilevering from either side of the joint and interleaved. A membrane, forming a drainage channel, will generally be provided beneath the metal plate or teeth elements. This form of joint, designed for large movements, is also outside the scope of this investigation.

Dam – a joint intended to provide a waterproof seal over the gap.

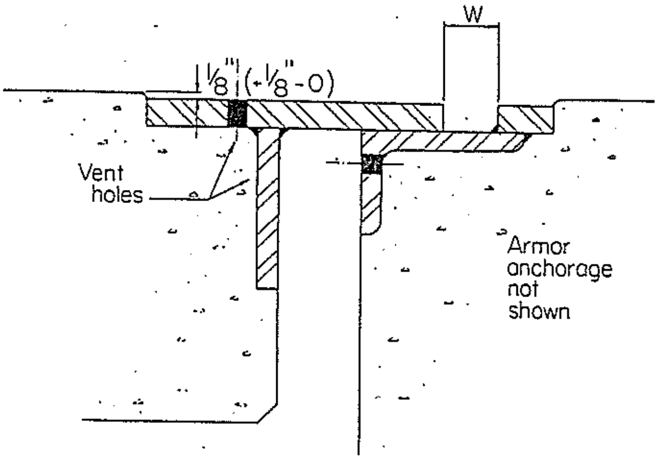
Poured sealant joint – these joints comprise an elastomeric sealant which is hot- or cold-poured into the joint gap against an appropriate backing material. Gun-applied non-slump sealants can be used in preference to poured sealants for bridges with significant camber or crossfalls. Sealant joints can accommodate only very small movements.

Open joint – open joint gap with or without armouring.

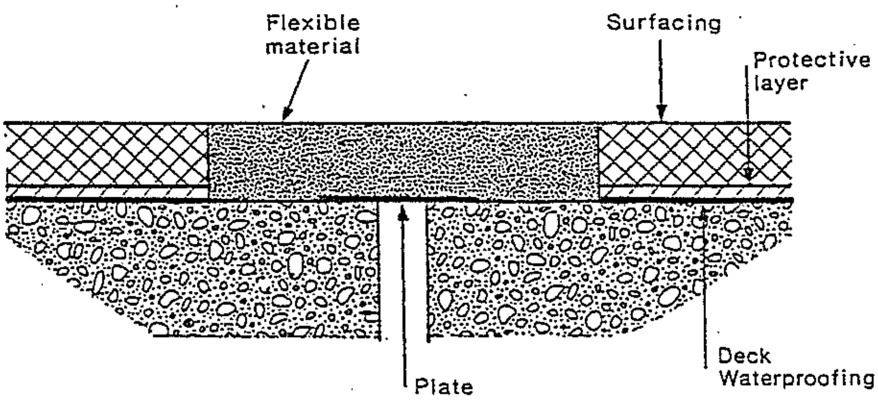
Figure 3.1 Deck expansion joint types (from Burke (1989) and UK DoT (1994b)).



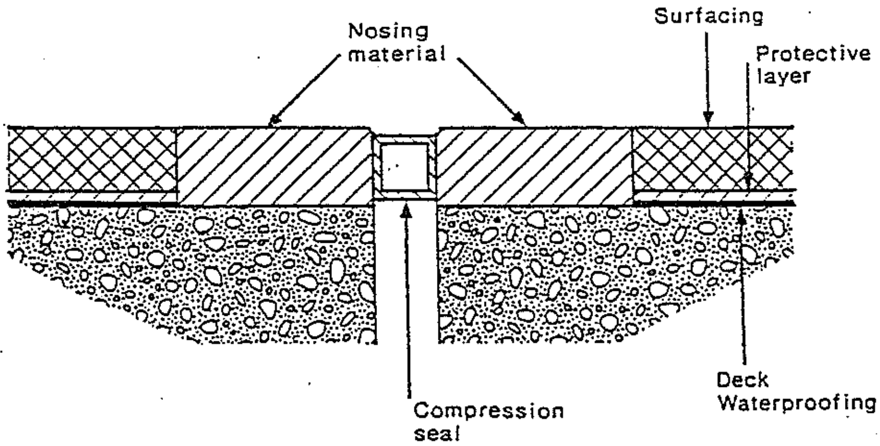
Buried Joint



Sliding Plate Joint

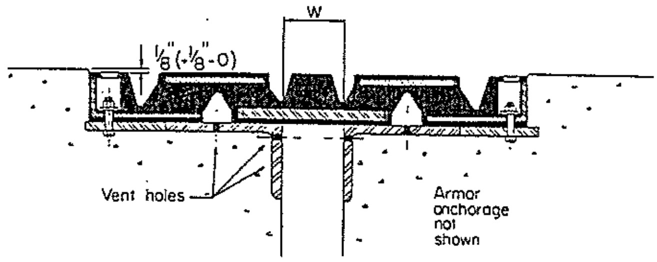


Asphaltic Plug Joint

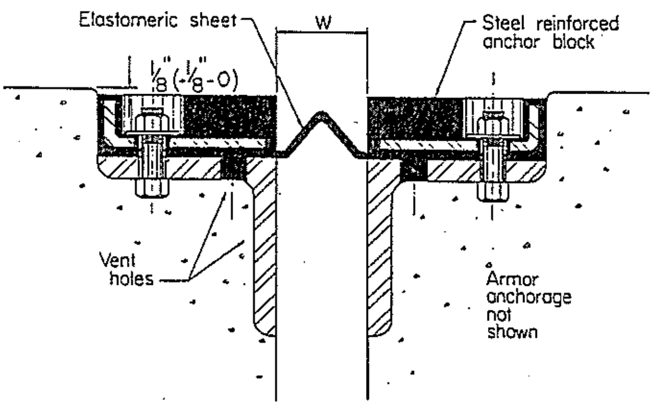


Compression Seal Joint

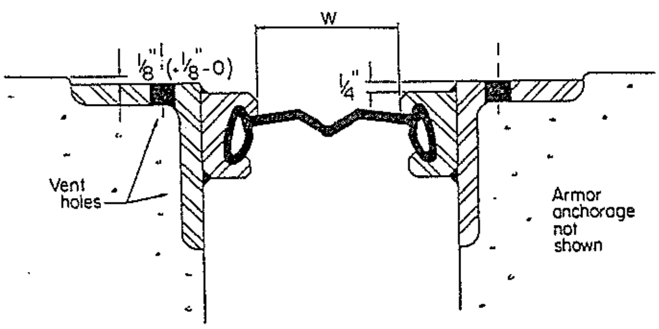
Figure 3.1 Deck expansion joint types (continued):



Reinforced Elastomeric Plank Joint

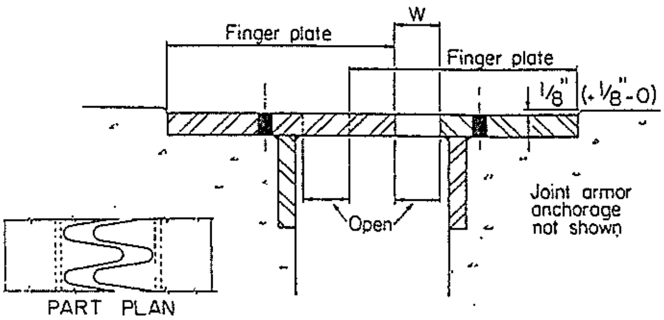


Elastomeric Sheet Seal

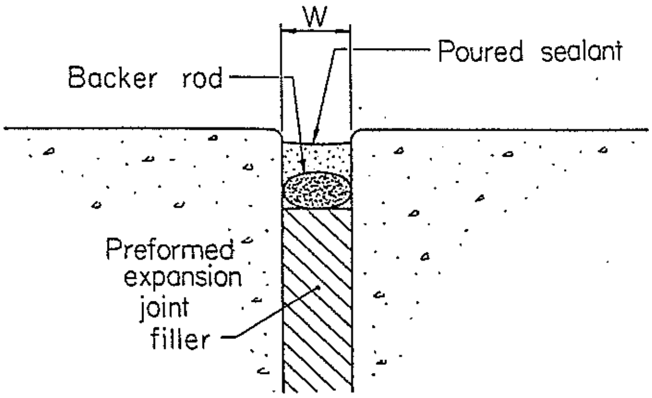


Elastomer in Metal Runner Joint

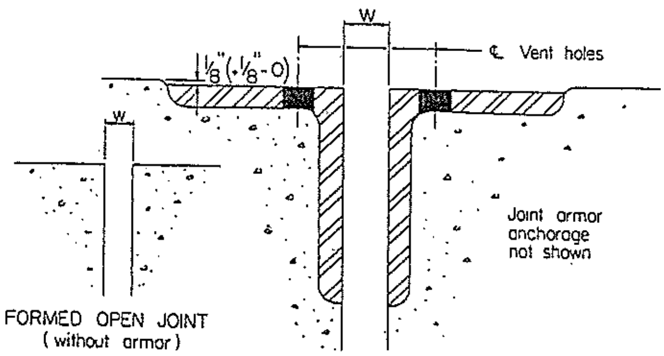
Figure 3.1 Deck expansion joint types (continued):



Cantilever Finger-Plate Joint



Poured Sealant Joint



Open Joint

Figure 3.1 Deck expansion joint types (continued)

3.2 Relevance of Literature to New Zealand Conditions & Practice

Very little literature was turned up from countries having similar climatic conditions and adopting similar road surfacing practices as New Zealand. The primary sources of published literature were the UK and North America where the major differences compared to New Zealand practice are:

- the use of thick relatively rigid pavements and surfacings (e.g. bitumen macadam, asphaltic concrete, concrete), compared to the widespread use of chipseal in New Zealand;
- the exposure of deck joints to conditions of ice and snow, and consequent use of salt to control icing and snow ploughs to remove snow from the carriageways in the UK and North America;
- New Zealand is an earthquake-prone country, whereas the UK is not, and most of the North American literature appears to emanate from areas that are less prone.

Asphaltic plug joints were developed originally for use with thick surfacings, and their performance is dependent on the material composition of the joints and on the joints having prescribed minimum dimensions. In their application to New Zealand situations, the thickness of joint for which these systems were originally developed will often not be feasible. Instead the result will be adopting reduced joint thicknesses. The cost of this form of joint is largely dependent on the extent of breakout required to place the volume of joint material onto the existing deck.

Price competition provides a real incentive for suppliers to minimise the thickness of this joint with increased likelihood of early failure. Chipseal surfacings are likely to result in more loose chip on the road surface than would be experienced in the UK. This makes the resistance of the joint material to intrusion by other material a more significant factor in New Zealand. The performance of this form of joint under earthquake response, which is relevant to their application in New Zealand, does not appear to have ever been investigated or tested.

Experience and trends in the use of nosing materials appears to be similar between that reported in the international literature and that in New Zealand.

Reinforced elastomeric plank joints are unlikely to be exposed to snow plough damage in the New Zealand environment. Also in New Zealand, they are unlikely to be required to operate at the low temperatures at which these joints would be expected to stiffen.

In other respects, the performance of these joints is likely to be similar in New Zealand situations to that experienced overseas. Certainly the same problems have been experienced, with fixings working loose or breaking, water penetrating through the bedding plane, and cover rubber being damaged. The international acceptance of this form of joint appears to be mixed.

Reinforced elastomeric plank joints provide substantial interconnection of the structural elements on either side of the joint, which has the disadvantage of transferring seismic forces across the joint. These forces may be significant even under small but relatively frequent earthquake events, inducing damage that requires remedial work.

Elastomeric seal joints, similar to the elastomeric plank joints, are unlikely to have to operate at such low temperatures in New Zealand as in the UK and North America. Ice accumulating in the trough formed by the rubber gland is likely to be less of a problem in New Zealand, but instead loose sealing chip may accumulate. Under earthquake response the advantage of this type of joint is that the transfer of seismic forces across the joint is usually limited, because the gland pulls out of its retaining jaws and breaks the connection. These glands can be replaced.

Cantilever finger plate, comb and tooth joints, while present in some older bridges, are a form of joint not generally in current use in New Zealand for short span bridges. These joints present problems for providing adequately for seismic movements.

3.3 Deck Joint Application Guidelines

In general, the international bridge design codes that were reviewed prescribe only functional requirements to be satisfied for deck joints. Papers and reports reviewed tended to report on observed joint performance, and to provide guidance on the use of different joint types. In general they did not provide recommendations for current practice in terms of joint types to be used for different situations.

The most useful guidance for selecting joint types is provided by the UK Department of Transportation (UK DOT) Standards BD33/94 (1994a) and BA26/94 (1994b). BD33/94 covers the main generic joint types available and the criteria to be satisfied for each type. In the UK, deck joints are subject to Highways Agency approval before they are adopted for use. The standard includes guidance for acceptable longitudinal and vertical movement, as shown in Table 3.1.

BD26/94 (1994b) gives guidance on the selection and installation of commonly used deck joints with diagrams of joint types (Figure 3.1) and expands on the content of BD33/94. To assist with selection the standard contains a table (Table 3.2) presenting a rating of key factors affecting joint performance, to be used as guidance in selecting joint types appropriate to particular applications.

In Ontario, the Ministry of Transportation publishes a list of Designated Sources, which identify the proprietary joints meeting the requirements of the Ontario Highway Bridge Design Code (Ontario Ministry of Transportation 1992). The joints listed are classified within one of three types by the method of seal retention. The selection of a particular type is dependent upon traffic volume, class and location of the highway, and whether traffic disruption for future maintenance can be tolerated.

The Hong Kong Structures Design Manual (Hong Kong Highway Department 1993) prescribes the use of filled or buried joints for movements of ±5 mm, the use of proprietary joints for larger movements, and the provision of drainage systems in conjunction with movement joints. Proprietary joints must be pre-qualified with the Highways Department.

Table 3.1 Acceptable joint movements
(extracted from UK Department of Transportation Standard BD33/94 (UK DoT 1994a).

Joint Type	Total acceptable longitudinal movement (mm)		Maximum acceptable vertical movement between two sides of joint (mm)
	Minimum	Maximum	
Buried joint under continuous surfacing	5	20	1.3
Asphaltic plug joint	5	40	3
Nosing joint with poured sealant	5	12	3
Nosing with preformed compression seal	5	40	3
Reinforced elastomer	5	*	3
Elastomer in metal runner	5	*	3
Cantilever comb or tooth joint	25	*	3

The limiting joint movements are for the serviceability limit state.
The minimum of the range is given to indicate when the joint type may not be economical.
* The maximum value varies according to manufacturer or type

3.4 Deck Joint Performance

The performance of different generic deck joint systems is given extensive coverage in the literature reviewed, and the content of the key references is summarised here.

3.4.1 Relevant Literature

UK Department of Transportation (1994b), in providing guidance on the selection of appropriate joint types, also indicates aspects of the joint system that have given rise to problems and measures that need to be taken to gain their best performance.

Barnard & Cunninghame (1997a, b) list the common defects and proposed repair methods for the different joint types. These papers provide both guidance on the selection of joint types, and ratings for the different joint types against a range of factors affecting performance. They also include assessments of whole-of-life costs for different types of joints in a range of locations, ranging from a minor single carriageway road to a two-lane motorway.

Joint Type	Movements at the joint (mm)									Traffic over joint						Joint Design	Materials Used	Condition of Substrate	Installation temperature °C			In service weathering	Detritus and corrosion	Site preparation and workmanship	Bond and anchorage
	Thermal Horizontal			Dynamic Horizontal			Dynamic Vertical			Frequency / Lane / Hour			Axle loads (kN)												
	0–15	15–50	50+	<0.05	0.05–0.10	>0.10	<2	2–4	>4	<10	10–50	>50	<10	10–40	>40				<10	10–15	>15				
Buried	M	H	N/A	L	M	H	L	M	H	L	M	H	L	M	H	M–H	M–H	M–H	L	M	H	M–H	L	H	M
Asphaltic Plug	L	M	N/A	L	L	L	L	L	M	L**	L**	M**	L**	L**	M**	L–M	M	M	L	L	M	L	L	M	L
Nosing (with sealant)	M	H	N/A	L	L	M	L	L	M	L	M	H	L	M	H	H	H	H	L	M	H	L–M	L–M	H	H
Reinforced Elastomeric	L*	L*	L*	L	L	M	L	L	M	M	M	H	L	L	M	M–H	L–M	M–H	L	L	L	L	M–H	H	H
Elastomeric in Metal Runners	L	L	L	L	L	L	L	L	L	L	L	M	L	L	L	M–H	M	N/A	L	L	L	L	M	M	H
Comb or Tooth Joints	L*	L*	L*	L	L	M	L	L	M	L	L	M	L	L	M	M–H	L–M	M–H	L	L	L	L	H	M	H
Transition Strip	L	L	L	L	L	M	L	L	M	L	M	H	L	M	H	M	M–H	H	L	M	H	L	L–M	H	H

* Assuming joint in correct design range	L = Low)
** Assuming correct binder type	M = Moderate) effect on performance
N/A = Not applicable	H = High)

Table 3.2 **Key factors affecting joint performance** (from UK DoT Standard BA 26/94 (1994b)).

Price (1984) provides a good description of the mode of failures of the generic deck joint types, identifying measures or materials that will improve the performance.

Burke (1989) provides a detailed presentation of each of the joint types and the nature of problems that have been experienced with them. He includes a general discussion of the features of each joint type, their development over time, problems that arose and improvements that have been incorporated, and measures necessary to obtain their best performance.

Manning & Witecki (1981) summarise the functional requirements for deck joints, briefly describe common failings with open and sealed deck joint types, and propose measures that should be adopted to overcome these failings. Recommendations are made on installation practices and minimum anchorage requirements.

Hill & Shirolé (1984) provide a description of the problems with different joint types and suggested remedial actions, and conclude with a short list of recommendations for deck joint design.

Dahir & Mellott (1988) report an evaluation of bridge expansion joints in Pennsylvania. They assess the performance of various joint brands using a weighted ranking system for the generic types of joints: compression seals, elastomer in metal runners, reinforced elastomeric joints, finger plate joints, and modular expansion joints.

Bramel et al. (1997) summarise the US experience with asphaltic plug joints (APJ), analysing the geographic distribution of problems and associated probable explanations. The approaches of different states to design guidelines, material specifications, and installation are briefly summarised. They consider that there is a need for basic research into the nature of asphaltic plug joints.

3.4.2 Performance

Buried joints – cracking of the surfacing generally occurs along the joint, leading to break-up of the surfacing and development of potholes. Rutting, tracking (or rutting), and joint leakage may occur.

Asphaltic plug joints – problems encountered have included cracking and leakage, tension splitting, delamination (generally as a debonding between the joint and the bridge deck surface), loss of aggregate causing potholes, tracking (or rutting), and flow of the binder on to the road surfacing.

Tracking (or rutting) is a problem that is more common in warmer climates, where the material tends to be more pliable. Tension splitting tends to be more of a problem in colder climates where the material may approach its glass transition temperature. It may also be caused by excessive strain or fatigue from a high number of loading cycles. Delamination generally propagates in the material adjacent to the bridging plate, but may also occur between layers within the joint as a result of poor construction.

Nosings – common problems are split or loose seals, debonding of poured sealants where they have been used, and cracking and break-up of the nosing material.

The majority of nosings are resinous or cementitious in content. Nosing materials which incorporate agents that increase flexibility (e.g. rubber, polysulphide, or pitch) are less prone to cracking, but some of these materials are not compatible with the gap sealant used.

Compression seal joints – common problems are leakage past the seal, splitting of the seal, and dislodgement of the seal.

Success with this type of joint has been mixed, with some agencies giving them high ratings while others have abandoned their use. Key to the success of this joint type has been considered to be proper installation, with the seal recessed 3 to 6 mm below the road surface to protect it from contact with traffic, but shallow enough so that it does not accumulate debris.

Current practice in the US is to bond these seals in place using a moisture-cured polyurethane material with a 75% solids content. Another high performance bonding procedure uses a flexible epoxy adhesive, elastomers, and abrasively cleaned joint surfaces.

Cellular seal joints – these joints generally have a similar form of joint detail to the compression seal. One of the major problems with these joints is that the seals exhibit compression set after being subjected to sustained compression. Further development of seal and adhesive materials is expected to lead to this joint type being suitable for many applications in the future.

Reinforced elastomer joints – problems with these joints have included: water leakage through the bedding plane and through joints between segments; transition strips (abutting the seals) that crack, break up and become debonded; plugs to cover the bolts are missing; bolts loosening or missing; joint surface wear and damage; and debris collecting in the grooves.

Elastomer in metal runner joints – problems with this joint type have included: split or dislodged seals; cracking or break up of the transition strip adjacent to the metal runners; wear and distortion to the metal runners; and debris filling the joint seal.

Sliding plate and finger-plate joints – these joint types were installed widely on older bridges. Problems experienced with these types of joint have included: lack of watertightness; bending and warping of metal plates and angles; lack of good fit between the contiguous sliding surfaces; road noise; and blockage of troughs installed underneath the plates to collect the drainage. These joints experience distress particularly if the joints are subject to differential vertical movement that the design did not allow for.

3.5 Deck Joint Procurement Methods

Procurement methods have been seen as a significant factor in the poor performance of deck joints. The following points are an extract from Barnard & Cunninghame (1997a), indicating the extent of the problem with the current range of joints and the limitations of present methods of procurement in the UK:

1. *This study has shown clearly that the present situation is unsatisfactory. Too many Engineers are unhappy with the performance of at least some types of expansion joint and there are wide variations in performance, particularly with regard to durability. This appears to be a consequence of methods used to select, purchase and install joints. At all stages, the pressure on the main Contractor and joint Supplier is to achieve the lowest supply cost and the shortest installation time. There is insufficient incentive to produce a durable joint.*

2. *The total cost to the Client and road user of providing a bridge with expansion joints throughout its life is much higher than the direct costs of purchase and installation of joints. Actual costs vary widely so it is difficult to make estimates, but the total cost is likely to be at least four times the direct cost. On very busy roads the direct cost of the joint is such a small proportion of the total as to be almost irrelevant.*

3. *Many motorways and urban roads are now so heavily trafficked that daytime lane closures would cause unacceptable delays to traffic. Maintenance and replacement of expansion joints often has to be carried out during night time closures and completed in time to re-open the road by morning. Also pressure on maintenance budgets is likely to continue. Both these factors affect expansion joint procurement, increasing the pressure to use joints which are both cheap to purchase and require a very short closure period to install. In these circumstances most Engineers will react to the immediate pressure to minimise closures, and long-term cost and durability may not be given adequate consideration.*

4. *There is serious concern among both Suppliers and Engineers over the effect of lane rental contracts*[1] *where joint installation is part of a large contract. The expansion joints are installed very near the end of the contract when the limited time available may be further reduced by slippage earlier in the programme. Also, large sums may depend on the time taken to install the joint – far in excess of the value of the joint. This puts unreasonable pressure on all parties to complete the joint installation without regard to quality and once again there is no balancing pressure to consider long-term costs or performance of the joint. However, the Working Group considers that the overall benefits of lane rental will ensure continued use of the system, so ways must be found to obtain good quality expansion joints within it.*

5. *The joint manufacturers and installers will (correctly) respond to the demands of the market so the present trend will continue, unless the emphasis can be switched away from short-term factors, to give due weight to long-term costs and benefits. There is a need for a procurement system which rewards long life joints and penalises those which fail prematurely.*

1 A lane rental contract is one in which the contractor accrues cost for the time over which a traffic lane is occupied.

It is concluded that worthwhile benefits would result from changing the present procurement method, but further work is required to develop an effective method of ensuring adequate service life. A promising solution being investigated by the Highways Agency is based on an approval testing of joints and quality assurance of installation, e.g. by an externally assessed Quality Management System.

6. *A requirement for a performance bond from the Supplier to guarantee an agreed service life could significantly improve the durability of expansion joints, if a robust system could be devised. This idea was examined in some detail, but experience in other areas of civil engineering suggests that there are serious difficulties with performance bonds and the Highways Agency do not recommend their use. Costs are increased and the benefits may be lost in disputes over the cause of defects. In the case of expansion joints, the size of bond necessary to cover the total cost of premature failure may be much larger than the value of the installation contract, which the BJA [Bridge Joint Association] felt would create difficulties for small firms. Further work would be required to overcome these problems and realise the potential benefits.*

Manning & Witecki (1981), reflecting Ontario practice, have the following to say on procurement:

The ultimate stumbling block in the development of a performance specification is the division of responsibility between the agency, the contractor and the joint supplier. The joint supplier will not accept responsibility for the performance of a joint unless he is also responsible for the installation. The contractor can only be held responsible if he is also responsible for the selection of the joint sealing system. However, the performance of the joint is also determined by the behaviour of the total bridge structure, which is largely a function of design, and by the agency's maintenance procedures, such as snow ploughing, over which the contractor has no control. Consequently, an approach to ensure satisfactory performance through the use of a performance guarantee is fraught with administrative and legal difficulties. It is unlikely to produce the desired result since the intent is easily circumvented. Where there is a delayed payment provision, the costs to the contractor can be passed on to the agency either by increasing the bid cost of the joint or by distributing the costs associated with the guarantee among other bid items. If defects develop and the cost of the repairs is likely to exceed the delayed payment, there is nothing to prevent the contractor from waiving the holdback and leaving the agency with the responsibility for repairing the joint.

In Ontario, a system of prequalification of proprietary deck joints has been used for several years. Physical tests on the joint materials are conducted and joint performance is evaluated, largely on the basis of engineering judgement, against the qualitative requirements defined in the OHBDC [Ontario Highway Bridge Design Code]. It is recognised that none of the joints currently in use completely satisfy all of the requirements. A list is published of those joints which most nearly meet the requirements and which are approved for use. The joints are classified within broad categories, such as compression seals, strip seals, and cushion seals. The designer then specifies the use of any approved joint from whichever categories are suitable for the particular installation.

The contractor is held responsible only for defects in materials and workmanship, responsibility for the former being passed along to the joint supplier. A performance guarantee is not considered feasible because required standards and acceptance criteria have not been defined adequately. There would also be serious difficulties in enforcement and, in any event, the cost is ultimately borne by the agency. The present procedure of controlling the selection of joint type, while allowing competing systems, where possible, has been found the most economic and workable system to date. Some specific requirements have been developed for gaps and for open and sealed joints in an attempt to ensure satisfactory performance without inhibiting new product development.

Similarly, in Hong Kong, movement joints can only be supplied by prequalified suppliers, but also they can only be installed by prequalified contractors. The Hong Kong Structures Design Manual (Hong Kong Highways Department 1993) emphasises the need for correct installation of proprietary joints to obtain satisfactory performance.

3.6 Design for Deck Joint Durability

Internationally, the trend is towards the elimination of deck joints by making the bridge superstructure continuous wherever possible. This approach is being incorporated into UK Standards. For example, the UK Department of Transportation Standard BD 57/95 (UK DoT 1995) states the following:

Continuous structures have proved to be more durable than structures with simply supported decks, primarily because deck joints have allowed salty water to leak through to piers and abutments. In principle all bridges shall therefore be designed as continuous over intermediate supports unless special circumstances exist. Such continuity may be either full continuity of the whole deck structure or partial continuity of usually the deck slab alone.

BA42/96 (UK DoT 1996), interpreting BD57/95, has taken this a step further:

In principle all bridges are to be continuous over intermediate supports and bridges with overall lengths not exceeding 60 metres and skews not exceeding 30° are to be integral with their abutments.

The Ontario Highway Bridge Design Code (Ontario Ministry of Transportation 1992) requires:

The number of deck joints and bearings in a structure to be the practical minimum.

Manning & Witecki (1981) comment that this approach was taken by the code because of the generally poor performance of deck joints.

Burke (1989), synthesising US experience and practice, makes the following observations:

Integral construction – bridges without deck joints – is being used by bridge designers to avoid problems associated with bridge deck joints. Over the last few decades many states have built bridges without deck joints.

> *The lengths of jointless bridges have increased from about 150 ft (46 m) to as much as 2700 ft (820 m) in recent years. Some of these bridges have a continuous deck with joints at the abutments but many are being built with integral abutments and no deck joints. ... Integral construction has been successful, and several transportation departments are now converting existing multiple-span bridges to continuous.*

Commenting on integral construction, Burke (1989) notes:

> *The justification for such construction is based on the recognition that for short- and medium-span bridges and for bridges of moderate lengths, significantly more damage and distress has been caused by the use of bridge deck joints than by the secondary stresses they were intended to prevent. In addition the elimination of costly joints and bearings, and the details and procedures necessary to permit their use, generally results in more economical bridges.*
>
> *Consequently, more and more bridge engineers are now willing to relinquish some control of secondary stresses primarily to achieve simpler and less expensive structures with greater overall integrity and durability.*

4. Current New Zealand Practice

4.1 Deck Joint Types

The proprietary sealed deck joint types available in New Zealand are summarised in Table 4.1. The five principal proprietary joint types currently in use are elastomer in metal runner (EMR) joints, reinforced elastomeric plank seals, compression seals, asphaltic plug joints (APJ), and poured sealant joints. Similar proprietary joint types are used internationally (McGovern 1999). In general, buried joints are not used in New Zealand because thinner chipseal surfacings are used.

4.2 Deck Joint Use & Distribution

The 21 road controlling authorities who responded to the postal survey manage a total of 5,089 bridges, and each of these authorities administer a number of bridges ranging from 45 to 900 bridges.

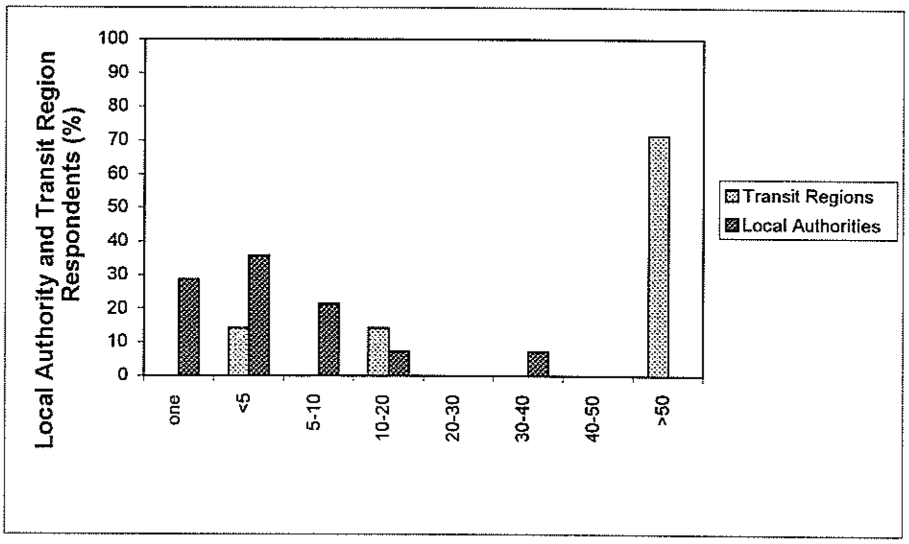
Bridge deck joints are used throughout the roading network, but the size and type of the bridges has significant bearing on the type of deck joints used, particularly when comparing the bridge stock of local authority regions with that of Transit New Zealand regions. The local authority bridge stock includes a high proportion of small, single-span bridges with no deck joints and, where they do exist, the joints are commonly small-movement, poured-sealant joints. Some of the larger municipal local authorities however have a higher proportion of multi-span bridges in their bridge stock. Greater use is made of deck joints in the Transit New Zealand bridge stock, which reflects the greater proportion of multi-span bridges.

The different nature of local authority and Transit New Zealand bridge stocks is illustrated by the comparison of deck expansion joint installations in the past ten years (Figure 4.1). Deck joint installations on local authority bridges are generally less than ten, whereas installations on Transit New Zealand bridges are commonly more than 50. Deck joint installation activity on Transit New Zealand bridges is primarily retrofitting of existing deck joints, which reflects the lack of new bridge construction.

GENERIC JOINT TYPE	JOINT BRAND	SUPPLIER	JOINT DETAILS
Elastomer in Metal Runner Joints	Miska BJ1 to BJ6	Environetics Civil Ltd	Available in a range of styles and dimensions for joint movements up to 125mm. Aluminium extrusions with neoprene rubber glands and flexible composite materials such as FC443 and FC446 to fill fixing cavity.
	D S Brown Steelflex	Environetics Civil Ltd	Joint type based on steel extrusions with neoprene rubber glands in a range of sizes for joint movements up to 125mm.
	Wabo Stripseal	Construction Techniques Ltd	Steel extrusions with neoprene rubber glands in a range of sizes for joint movements up to 200mm. Wabocrete elastomeric concrete commonly used in nosings.
Reinforced Elastomeric Plank Joints	Waboflex SR2.5 to SR13	Construction Techniques Ltd	Range of plank joints accommodating movements from 50mm up to more than 300mm.
Compression Seals	Wabo Compression Seals	Construction Techniques Ltd	Range of neoprene compression seal sizes accommodating movements between 20mm and more than 80mm.
	Miska Neoprene Compression Seals	Environetics Civil Ltd	NH Series seals designed for heavy traffic applications. Range of seal sizes to accommodate movement from 18mm to more than 70mm.
	Jeene	Construction Techniques Ltd	Hollow neoprene profile that is inflated at time of installation to ensure a watertight bond at the joint sidewalls. Range of sizes to accommodate movement between 25mm and 100mm.
Asphaltic Plug Joints	Prismo Thormajoint	Works Civil Construction Ltd	Thormajoint available as a standard option where seal depths are 50mm and greater. Joints are installed at nominally 500mm wide to accommodate joint movement of up to 50mm. Slimline joints can be used where seal depths are between 25mm and 50mm.
	Techniflex PMB403 (and PMB 401)	Bitumen Supplies Ltd (previously Technic Industries Ltd)	Techniflex PMB 403 Bridge Joint System should be used in depths of at least 30mm with a joint width of between 100mm and 300mm.
Poured Sealant Joints	Colpor 200	Fosroc Ltd	Cold poured, two part coal tar/polyurethane sealant. Suited to narrow joints where movement relative to joint width is high.
	Sikaflex T68W	Sika (NZ) Ltd	Cold poured, two part coal tar/polyurethane sealant.
	Thioflex 600	Fosroc Ltd	Gun-applied, single pack, three component polysulphide sealant. Appropriate for bridges with significant camber or crossfalls.
	Sikaflex T68NS	Sika (NZ) Ltd	Gun-applied two part coal tar/polyurethane sealant. Appropriate for bridges with significant camber or crossfalls.
	Pliastic 77	Fosroc Ltd	Hot poured rubber and bitumen-based sealant. Suited to wide joints where very little movement relative to joint width is expected.

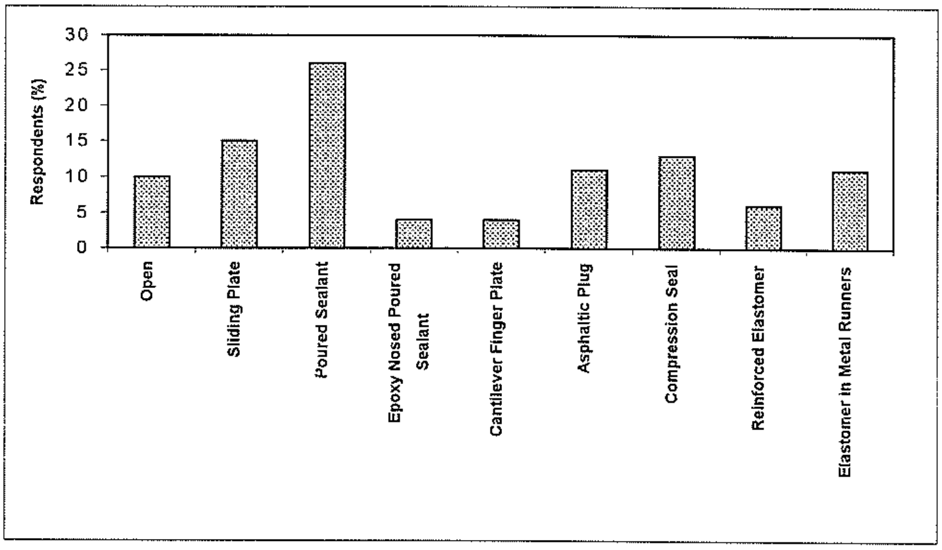
Table 4.1 Deck joint types available in New Zealand.

Figure 4.1 Number of deck expansion joints installed in the past ten years on local authority and Transit New Zealand road bridges.



Trends in the use of different types of deck joints installed in the past ten years are presented in Figure 4.2. The most universally used joint is a poured sealant joint which reflects not only the nature of the local authority bridge stock but also the large percentage of cast in-situ concrete bridges in the Transit New Zealand bridge stock, constructed before 1950, that include small-movement poured-sealant joints. The continued use of unsealed deck joint types such as sliding plate and open joints suggests a lack of appreciation by some authorities of the impact that water leakage can have on the substructure of a bridge. On the other hand, sealed deck joints other than poured sealant joints make up more than 40% of deck joints installed.

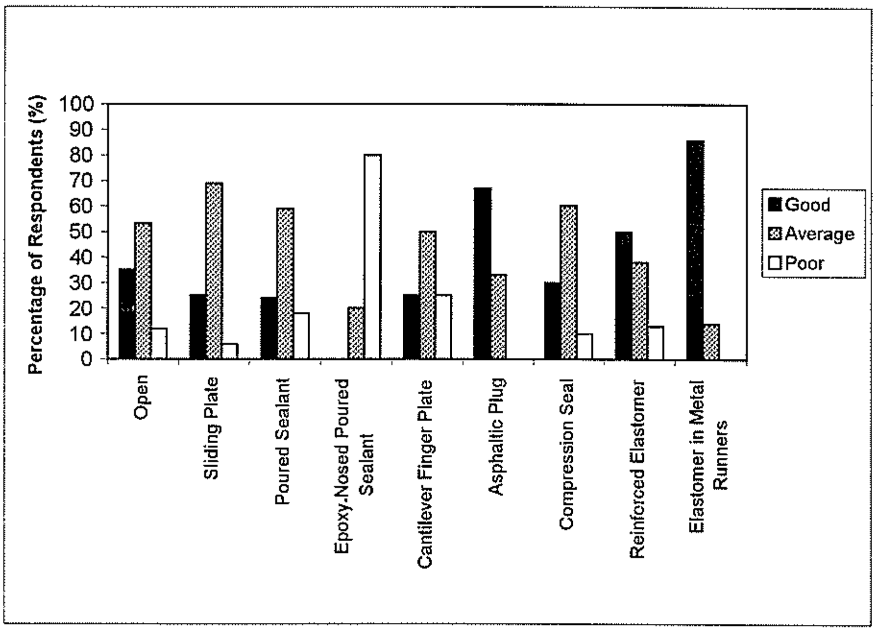
Figure 4.2 Deck joint types installed in New Zealand road bridges in the past ten years.



4.3 Deck Joint Application & Performance

The performance ratings of expansion joints known to road controlling authorities are presented in Figure 4.3. The ratings show some variability and, in some cases, are difficult to assess because the response rate to the survey was low, but the data show some clear trends. The predominant rating given to EMR and APJ joints was good which indicates that they give a better than average performance. At the other end of the scale, epoxy-nosed poured sealant joints show below average performance. All other joint types gave satisfactory performances, with most respondents rating their performance as average or good.

Figure 4.3 Performance of deck expansion joints, as rated by road controlling authorities.



The following assessments of commonly used joint types are of their application and performance, and include faults and defects. This summary is based on comments made by road controlling authorities and deck joint suppliers, as well as the assessment made of the joints during the on-site inspection. A summary of the bridges that were inspected, with the history and assessed performance of their joints, is included in Appendix 4.

4.3.1 Open Joints

Open joints are still relatively common in the existing bridge stock. However, the trend is towards their replacement with sealed deck joints to prevent deterioration of the bridge substructure, although some bridge controlling authorities indicated that open joints have been installed on bridges within the last ten years (Figure 4.2). In some bridge designs, joint leakage may only affect relatively massive concrete abutment elements because the beams are physically separated by rubber bearings from the deck. Thus open joints may have little effect on durability. In other instances leakage of water and detritus through joints may cause deterioration of structural members. Also removal of build-up of debris requires constant maintenance. Road controlling authorities are generally satisfied with the performance of open joints (Figure 4.3) which may indicate that deterioration of the bridge structure is not a major factor in bridge maintenance.

Other problems encountered with open joints include stones wedging in joint gaps causing deck spalling, looseness of steel angle armour to joint nosings, failure of nosings, and accumulation of road debris in joint gaps.

4.3.2 Sliding Plate Joints

Sliding plate joints are still relatively common on the existing bridge stock, and 15% of road controlling authorities indicated that they were still in current use (Figure 4.2). These joints are probably more common on local authority bridges on which traffic volumes are generally lower. Road controlling authorities were overall satisfied with their performance.

Sliding plate joints allow leakage of water and detritus onto structural bridge members, causing deterioration like that caused by open joints. Although overseas practice indicates that drainage systems are installed beneath these joints, such installations do not appear to be common in New Zealand bridges.

A common universal problem is the failure or fatigue of fixings holding the plates. These joints will fail rapidly if any vertical movement occurs at the joints. Other problems encountered include joint gaps filling with debris, excessive traffic noise, and distortion of plates and angles under traffic loads.

4.3.3 Cantilever Finger-plate Joints

Cantilever finger-plate joints are more commonly used for large-movement joints, and are less common on New Zealand bridges. The joints are rarely used in current practice (Figure 4.2), but the performance of any existing joints is rated as generally satisfactory (Figure 4.3) by road controlling authorities.

Leakage and accumulation of debris is also a problem, although some of these joints may include waterproof seals. Their lateral movement capability is limited. As with sliding plate joints, fatigue and failure of fixings is another problem encountered.

4.3.4 Poured Sealant Joints

Poured sealant joints are the most common type of deck joints used on the existing bridge stock. The joints are commonly used at small-movement construction joints and especially at split diaphragm joints in reinforced concrete T-beam bridges that were constructed before 1950. Poured sealant joints are also used at small-movement deck joints in new bridge construction. Existing poured sealant joints are often retrofitted with similar materials when they fail, although in specific applications their replacement with compression seals and APJs is becoming common.

The term "poured sealant" is used here to encompass both hot- and cold-poured sealants as well as gun-applied materials (Table 4.1). For relatively narrow joints where large movements are expected relative to the joint width, then pourable 2-part coal tar/polyurethane sealants (e.g. Fosroc Colpor 200, Sikaflex T68W) have been used. If the bridge deck includes significant camber or crossfalls, then pourable sealants are not suitable and gun-grade materials (e.g. Fosroc Thioflex 600, Sikaflex T68NS) can be used. In wide joints where very little movement is expected, hot-poured rubber/bitumen sealants (e.g. Fosroc Pliastic 77) are available.

Road controlling authorities indicated general satisfaction with the performance of poured sealant joints (Figure 4.3), although field inspections suggested that the performance of these joints is variable and relies heavily on an appropriate joint design to accommodate the expected movement, and good installation practice to ensure adequate adhesion.

The most common problem with sealant joints is the embrittlement and failure of existing joint materials, with associated loss of adhesion and removal of the sealants by trafficking. Adhesion is also a critical factor when re-installing poured sealant joints and a key factor is adequate preparation of joint surfaces. It is critical to remove all traces of the previous joint material or bitumen, to which most sealants are sensitive.

Other problems encountered include cracking of concrete nosings, deterioration of flexcell backing material due to rotting, distortion resulting in the sealant "pushing out" due to unexpected joint movement, and failure of joint sealant due to cyclic loading causing spalling at the edge of precast panels.

A number of bridges that were inspected included poured sealants at some or all of the deck joints. In most cases the joints were concealed below the deck seals and, unless significant deterioration had occurred, the joint location was marked only by a linear parting of the deck seal. Two bridges retrofitted with Fosroc Colpor 200 sealant joints were of this nature, and the joints were assessed to be performing satisfactorily because there was no sign of water leakage over the bridge superstructure.

Two multi-spanned bridges fitted with Fosroc Pliastic 77 into saw-cut joints showed poor performance at some joints where the sealant had been physically removed by trafficking. Some aspects of joint design, including selection of an appropriate sealant to suit the expected joint movement, are thought to have contributed to this failure.

4.3.5 Epoxy-Nosed Poured Sealant Joints

Epoxy nosings were principally used in combination with poured sealants and compression seals for a period in the 1970s and 1980s but currently are very little used (Figure 4.2). This can be related to the poor performance of these joints and the general dissatisfaction of road controlling authorities with them (Figure 4.3).

The nosings commonly show regular transverse cracks causing loss of adhesion of the sealant, resulting in joint leakage. Joint leakage is also commonly promoted by loss of adhesion of the nosing to the concrete deck. Abrasion wear of the nosings exposes the sealant material to trafficking followed by rapid failure of the joint.

4.3.6 Asphaltic Plug Joints

Asphaltic plug joints are becoming increasingly common as an option for retrofitting existing joints. They are regarded as a good option for use on small-movement joints to achieve waterproofness and improve rideability, and are generally resilient under high traffic volumes. Road controlling authorities gave a predominantly good performance rating for these joints (Figure 4.3).

APJs are available from Works Civil Construction (Prismo Thormajoint) on a supply-and-install basis, and from Bitumen Supplies Ltd (Techniflex PMB Joints), formerly Technic Industries Ltd, on a supply-only basis (Table 4.1).

Twelve bridges with APJs installed were inspected. The joints had been in service for between 2 to 10 years and in most cases were functioning well. APJs were invariably used for retrofitting poorly performing poured sealant joints or compression seals to improve both waterproofness and rideability. Problems encountered included minor cracking along the length of the joint both at the joint edge and within joint material, but the cracking did not appear to be compromising the waterproofness of the joints. However over time, this cracking could lead to joint deterioration caused by hydraulic pumping action under the passage of traffic.

In some cases cracking was more evident in the shoulder area where the joint was lightly trafficked.

Standard practice in the UK is to install APJs with a nominal width of 500 mm and a depth of 50-100 mm. However, the lack of seal thickness on bridge decks in New Zealand has seen the introduction of thinner, narrower joints. The use of small dimension joints may also be driven by commercial pressure to reduce the cost of joints. In general, smaller joints are likely to be able to accommodate less horizontal movement, and may be more susceptible to fatigue under high traffic volumes.

Eight of the bridges inspected included 500 mm wide x 50 to 70 mm deep joints. All of these joints were performing well. Other examples included joint widths of between 300 mm and 150 mm, with thicknesses of between 20 mm and 30 mm. In one bridge a reduced-thickness APJ had been installed on a joint where the movement was clearly too large and failure had occurred. On another bridge, some of the 30 mm-thick joints showed tracking and potholing in the outer wheel path under relatively high traffic loads. This was attributed to fatigue of the joint material as a result of the reduced joint thickness. All other reduced dimension joints appeared to be performing adequately, including 220 mm wide x 20 mm thick joints after seven years in service.

The general impression is that thinner, narrower APJs may be serviceable if movements are small enough and traffic loads are not high. Thin joints may fail prematurely because of fatigue under high traffic loads, or may crack due to excessive joint movement.

In some APJ installations, joint thicknesses are increased by excavation into the concrete bridge deck. Care is required to ensure that the deck is thick enough to allow excavation and that the cover to deck reinforcement is not compromised.

APJs are inappropriate for use on bridges that have significant crossfalls or where joints are skewed to the direction of traffic flow. Where joints are skewed, traction forces imposed by the trafficking can cause flow of the binder material in the joint. On one of the bridges which included significant joint skew, the joint material had flowed out of the joint cavity. Joint thicknesses as low as 25 mm and lack of adequate bond to a galvanised bridging plate may also have been contributing factors to the joint failure.

Failure of several APJs on one of the bridges was directly attributed to the condition of the existing joint hardware. The original joints were compression seals with metal angle armouring, and the metal angles were left in place. On some joints the fixings to the metal angles were loose and movement under trafficking had caused premature failure of the plug joints. Where the metal angles were still adequately fixed, the joints were performing well after two years.

Other problems encountered by road controlling authorities include physical damage caused by braking vehicles, damage by horses, loss of bond between the joint material and abutting asphalt surfacing, and loss of bond to the bridging plate. The fate of joints when bridge deck surfacings are removed by milling during replacement or maintenance must be addressed.

4.3.7 Reinforced Elastomer Joints

Historically both elastomeric plank and elastomeric sheet seals have been used in New Zealand. Joint brands encountered on existing bridges included Felspan, Waboflex and Transflex, but Waboflex elastomeric plank seals are the only type currently available (Table 4.1). They include a range of joint sizes up to very large movement joints for long span bridges. This joint type has little current use by road controlling authorities (Figure 4.2) for joint movements under 125 mm, but where they are in use there is general satisfaction with their performance (Figure 4.3).

Five bridges that included reinforced elastomeric joints were inspected. Two had elastomeric sheet seals and three had elastomeric plank seals. In four of the five bridges the joints were affected by deterioration in the form of cracked nosings, loss of steel angle armouring to concrete nosings, deterioration of the adjacent surfacings, missing hold-down bolt caps, and some looseness and surface wear of the plank segments. Although no signs of leakage were observed on these bridges it could be expected considering the nature of the joint deterioration.

In the fifth bridge, the seal element in two elastomeric sheet seals had ruptured as a result of punching by chip that has accumulated in the joint gap, under traffic loads.

A common problem encountered by road controlling authorities is the failure and loosening of hold-down bolts, which can be related to the movement stiffness of these joints. Elastomeric plank joints especially are very stiff and must inevitably develop substantial forces on their anchorages and in the bridge structure. The installation of appropriate anchor bolts is important. Normal-setting epoxy adhesives retain flexibility and provide better durability than masonry fasteners and set accelerated epoxy adhesives. Other problems encountered include delamination of composite planks exposing steel plates, curling of planks at the nosing edge of joint, loosening of joint components causing excessive road noise, build-up of chips and debris in the joint gap (elastomeric sheet seals), and loss of rubber plugs protecting the fixings.

The joints rely heavily on correct installation. If the joints are installed slightly above the carriageway level then problems such as joint element wear, poor rideability and excessive noise generation can be encountered. Joint installation may be compromised when the joint recess provided in the deck construction does not meet the dimensional tolerances required. If the joint recess is not flat enough the joint will not be adequately supported along its length and deterioration will result.

4.3.8 Compression Seal Joints

Compression seal joints have been used on New Zealand bridges for a number of years. Some early examples were susceptible to lack of waterproofness and physical loss of the seal elements, but the more recent use of adhesives to retain and waterproof the seal elements has significantly improved their performance. Some road controlling authorities make extensive use of compression seals based on a good performance record, whereas others make virtually no use of them. In general, the performance of compression seals is rated as satisfactory (Figure 4.3).

Compression seals are available from Construction Techniques Ltd and Environetics Civil Ltd (Table 4.1), and include sizes that accommodate joint movements up to 100 mm. Small profile compression seals are more commonly used on bridge decks.

Six bridges which included compression seals were inspected. The performance of the joint elements was good on all bridges with no signs of deterioration, and the joints were waterproof. Deterioration on three of the joints was related to the epoxy nosing. The nosings were cracked transversely at regular intervals, the interface between the back of the nosings and the deck seal had failed due to debonding of the nosing from the deck, and in one case the nosing was proud of the deck seal causing the epoxy to deteriorate.

Problems encountered by road controlling authorities include damage to the seal element because of stones punching down under traffic loads, removal of the seal element by vandals, deterioration of the seal element from spilled bitumen, and build-up of debris in the joint gap.

As with poured sealant joints, adhesion of the seal element to the nosings is very important, and removal of all traces of bitumen or existing sealants is essential when installing them. A joint gap width that is suitable for a compression seal is often formed by sawcutting.

4.3.9 Elastomer in Metal Runner Joints

This joint type has a long history of good performance on New Zealand road bridges. Almost 90% of road controlling authorities rated their performance as good (Figure 4.3), and they are routinely used in new bridge construction.

Eight bridges were inspected that included elastomer in metal runner joints. The joints on seven of the bridges were waterproof and most were showing excellent performance. The joints on four of the eight bridges had been in service for approximately 20 years.

The joint on one bridge was deteriorating and leaking because the joint had been installed proud of the carriageway level. The resultant impact forces had debonded the epoxy nosing from the deck, exposed the hold-down bolts and loosened the metal angle armouring, but the rubber seal element remained intact.

Joints exposed on a relatively new bridge were installed inside 25 mm-high concrete nosings cast as an integral part of the deck. The joints were performing well but the deck seal was substantially lower than the concrete nosing, reducing the ride quality of the deck. A seal overlay was planned to remedy this.

All joints inspected had a significant build-up of stones and debris in the joint gaps and this could theoretically result in rupturing of the seal element. In one case, the joint appeared to have actually been chipsealed over. In no cases was the seal element damaged, but the potential is there for this to occur and regular cleaning would prevent this.

The joints inspected had movement gaps ranging between 30 mm and 70 mm, and traffic noise was greater with the wider gaps. When the movement gap exceeds 100 mm, the joint may pose some concerns to cyclists.

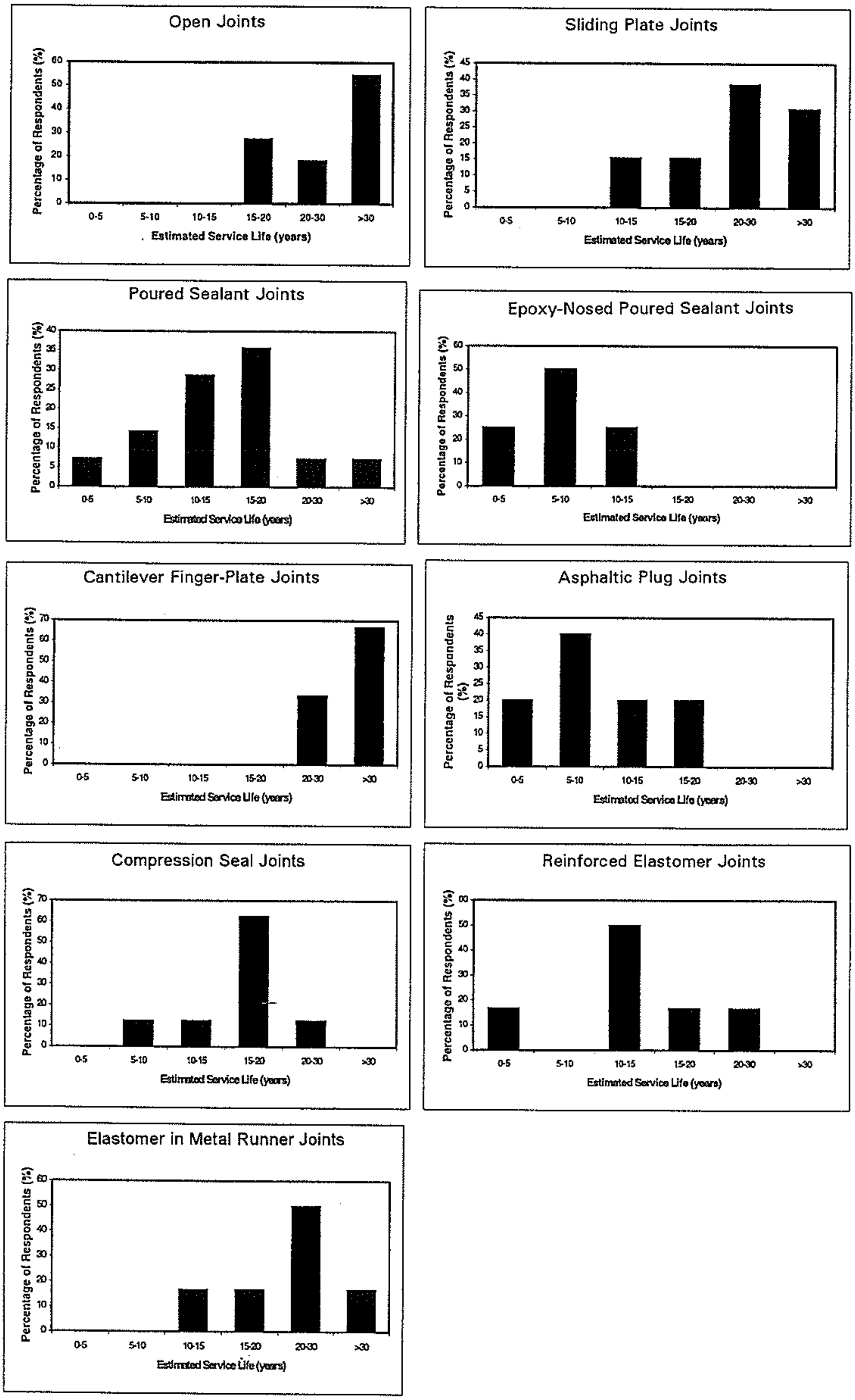
Some bridges carried the joint up into the kerb at right angles to the deck. This is a desirable design detail that prevents water draining over the side of the bridge and onto the bridge substructure.

4.4 Deck Joint Durability

4.4.1 Service Life

The service life for a deck joint is defined as the period of time before the function of the deck joint has been reduced to a point where it is no longer acceptable.

Figure 4.4 Estimated service life of deck joints, obtained from New Zealand road controlling authorities.



Such deterioration may include leakage, deterioration of nosings and armourings, and deterioration of the joint components themselves. Obviously service lives are likely to be variable for all joint types because of the variety of service conditions as well as the qualities of the joint. The level of deterioration deemed to be acceptable will vary between road controlling authorities, and will also be dependent on bridge design. For example, joint leakage may be more acceptable in some bridge designs in which critical structural elements are isolated from the leakage area.

The service life estimates indicated by New Zealand road controlling authorities for each joint type are shown in Figure 4.4. These graphs show a range of service life estimates for each joint type, so any attempt to produce a single value represents a simplification of the real situation. The graphs however show the following trends:

Unsealed joint types – include open joints, sliding plate joints, cantilever finger-plate joints, and show estimated service lives mainly in excess of 20 years and in some cases more than 30 years. Some respondents indicated service lives of 10 to 15 years for sliding plate joints, and this may reflect problems with the durability of fixings on these joints.

Poured sealant joints – show a range of estimated service lives of between 0 years and more than 30 years, and the most common response was 10 to 20 years service life. The range reflects the sensitivity of poured sealants to installation practice and to excessive joint movement. The estimated service life for *epoxy-nosed poured sealant joints* is mainly less than 10 years.

Asphaltic plug joints – give service lives for up to 20 years. The most common response was a service life of 5 to 10 years. Asphaltic plug joint suppliers claimed an expected service life of 10 years.

Compression seal joints – give an estimated service life ranging between 5 and 30 years, but the most common response was a service life of 15 to 20 years. Suppliers claimed a minimum expected service life of 15 years.

Reinforced elastomer joints – have an estimated service life that ranges from 0 to 30 years, but the most common response was a life of 10 to 15 years. The range of these estimates reflects the importance of installation on the performance of these joints. The suppliers of these joints indicated that service life is dependent on "... usage and fixing conditions", and that regular joint maintenance is required.

Elastomer in metal runner joints – show service life estimates of between 10 and more than 30 years, and the most common response was a service life of 20 to 30 years. This aligns with the superior performance of these joints (Figure 4.3). Joint suppliers indicated an expected service life of at least 15 years, and in most cases this estimate reflects the life of the joint seal and the nosings. The joint extrusions are expected to last considerably longer than this, and in some cases to last for the life of the bridge structure.

4.4.2 Whole-of-Life Costs

The service life achieved by joints is variable (as shown in Section 4.4.1) with significant differences between joints of the same type as well as between different types. Premature failure of a joint, for whatever reason, incurs both the cost of joint replacement plus indirect costs such as traffic delays. Therefore selecting joints on initial cost alone is not appropriate. Joints should be selected on the basis of long-term performance.

Long-term performance of joints is used as the principal basis for selection by some New Zealand road controlling authorities. However the assessment of long-term performance is generally intuitive, based on the knowledge of individual consultants and their experience derived from managing a particular bridge stock over a number of years. Sound joint selections are made on this basis. Where road controlling authorities frequently change their bridge consultants or the consultants are only rarely involved in bridge joint replacement, then the joint selection is more likely to be based on initial cost, because of their lack of knowledge about long-term performance.

Calculation of the whole-of-life costs for joints would provide a basis for joint selection based on long-term performance. Barnard & Cunninghame (1997b) investigated whether whole-of-life costing could be used as a selection method to achieve this objective. They broke down the cost of constructing and maintaining an effective bridge joint over the whole life of a structure into the following elements:

- Joint supply and labour for the initial installation;
- Additional contract costs (e.g. client and contractor administration, establishment, etc.);
- Road user delay costs;
- Structural damage to bridge substructure (e.g. due to leaking joint);
- Joint maintenance;
- Joint replacement at the end of the service life of each joint.

Barnard & Cunninghame (1997b) trialled two methods for calculating the whole-of-life costs. The first followed the procedure of evaluating future replacement costs by reducing them to their present day value using a discount rate. The second evaluated the annual "Average Annual Cost" where the total costs of a joint are averaged over its assumed life and is primarily limited to joint replacement. The latter method was found to be simpler and gave very similar results to the former method.

Both methods for calculation of whole-of-life costs depend heavily on service life predictions for the different deck joints.

To calculate meaningful whole-of-life costs for deck joints relies on two key factors. First, the service lives for the joints need to be well established and accepted by both suppliers and users. Second, the supply, installation and other costs need to be directly comparable for the different types of joint.

The service lives that are perceived by New Zealand road controlling authorities vary considerably (Figure 4.4). This means that the calculation of a single value for each joint type would be unreliable and misleading. In addition the supply and installation costs submitted by deck joint suppliers were found not to be readily comparable because of the variety of joint sizes, and different allowances made for preparation when retrofitting existing joints. For these reasons whole-of-life costs were not calculated in our study. However indications of the supply and installation costs for different generic joint types are provided in Table 4.2.

The use of whole-of-life costs as an aid to deck joint selection may be difficult in New Zealand because useful and acceptable data are lacking, as illustrated in this study. Appropriate data may be available when selecting joints for a specific structure but are unlikely to be widely applicable. A better option may be to utilise the experience of road controlling authorities by collecting data on joint maintenance and installation expenditure on an ongoing basis. In this way a database could be assembled to provide a more reliable basis for calculation of whole-of-life costs.

With respect to the total cost of bridge deck joints, some of the findings of Barnard & Cunninghame (1997) are applicable to New Zealand conditions. They concluded that the total cost is likely to be at least four times the direct cost, with traffic management and road user delay costs being the most significant item. On very busy roads the direct cost of the joint is an even smaller percentage of the total cost.

Table 4.2 Supply and installation costs for deck joints.

Generic Joint Type	Typical Supply & Installation Cost (Type of seal)	Typical Retrofit Structure Preparation and Joint Installation Time
Asphaltic Plug Joint	$300-$1,100/m for supply and installation, depending on size and type of joint	1.5-2 hours/m
Compression Seal Joint	$40-$400/m for supply only, depending on size of seal element (Wabo Compression Seals)	Depends on extent of joint preparation required. Replacement of seal element only is very quick.
Elastomer in Metal Runner Joint	$3,000/m for supply and installation, including proprietary nosings and armouring (Wabo Strip Seal SE300 with Wabocrete nosing)	4 hours/lane width
	$535-$650/m for supply only (Miska BJ2 and Miska BJ5 joints)	N/A
Reinforced Elastomer Joint	$2,000/m for supply and about $300/m for installation (Waboflex SR6.5 – a joint designed to accommodate total movement of about 150mm)	4 hours/lane width

5. Discussion

5.1 Deck Joint Use & Application Practice

Comparison of international best practice (section 3 of this report) with New Zealand practice (section 4) shows that, in general, the local experience with deck joints is similar to that in the UK and North America. Joint types used are similar except for those joint types specifically designed for thick asphaltic surfacings, which are not common in New Zealand. The performance and specific problems encountered with deck joints are also comparable, and the durability of deck joints in the UK raises similar concerns in New Zealand. Deck joint performance relies heavily on selection of an appropriate joint type coupled with correct detailing and installation.

Any type of joint in a bridge deck is a potential source of weakness in the structure, and no one joint type or improvement in practice can hope to satisfactorily address this problem. For this reason, the international trend is away from using deck joints by making bridges continuous and, where possible, making integral abutments. Except for quite short bridges, integral abutments have seen only limited application in New Zealand in recent times, and this trend has yet to catch on, because of the widespread use of precast prestressed concrete components for bridge superstructures in New Zealand.

Sealed deck joints are required to be used on UK bridges because of the potential for deterioration of the bridge substructure as a result of water leakage. The risk of deterioration is further heightened by the use of de-icing salts. Some New Zealand road controlling authorities continue to install unsealed joints (e.g. open joints, sliding plate joints). In some bridge designs, water passing through unsealed joints does not affect key structural elements and the risk of deterioration of the bridge substructure is minor, provided debris carried through the joints is frequently removed. However, in general, the use of unsealed joints poses risks to the durability of the bridge substructure, and sealed joints should be the preferred option for the retrofitting required when existing unsealed joints become unserviceable.

The majority of deck joints used in New Zealand are small-movement joints originally fitted with poured sealants. However, the variability in the perceived service life and performance of poured sealant joints reflects the need for appropriate selection and correct installation. Nevertheless poured sealants remain a viable alternative for retrofitting, provided that preparation of concrete surfaces in the joint recess is adequate. This is a key to achieving the necessary adhesion of the sealants. Both small profile compression seals and asphaltic plug joints are also viable alternatives for retrofitting these joints. Developments in compression seal adhesives have improved the performance of these joints and as a result more extensive use of these joints is expected.

Asphaltic plug joints have become a relatively common retrofitting option, but the joints used in New Zealand are often thinner than those developed in the UK. Adequate joint thickness is sometimes achieved by excavating into the concrete deck itself at the joint recess, which may expose reinforcing steel in the deck. However, this practice should not be encouraged as it may compromise the durability of the deck. The general performance rating for these joints was good and the thinner joints appeared to be performing adequately where joint movements were small enough and traffic loads not high. However, further work is required to understand the performance and limitation of these joints under New Zealand conditions.

The best performing joint type in both New Zealand and UK experience is the elastomer in metal runner joint, which should perform satisfactorily over extended periods of time with replacement of seals as required.

Limitations in methods of deck joint procurement in both the UK and North America are considered in section 3.5 of this report. The general concerns expressed are that joints tend to be selected to achieve the lowest supply costs and shortest installation times, and that the durability and long-term performance of the joints are not a critical factor. In New Zealand conditions, the increasing use of reduced dimension asphaltic plug joints may be, in part, related to price competition. However, although cost is a factor in joint selection for New Zealand road controlling authorities, experienced bridge consultants will tend to choose deck joint types with proven long-term performance. Bridge consultants or authorities lacking experience in deck joint selection and appropriate knowledge may choose joints with low initial cost, or those which have been marketed most effectively by deck joint suppliers. For this reason, guidelines for deck joint selection and use which are applicable to New Zealand conditions need to be developed in order to improve deck joint performance. Such guidelines need to be available to all road controlling authorities and their consultants.

5.2 Guidelines for Selection & Use of Deck Joints

The *Bridge Manual* and the *Bridge Inspection and Maintenance Manual* (Transit New Zealand 1994, 1991) are the most appropriate documents in which to include guidelines for selection, use and maintenance of deck joints.

5.2.1 Transit New Zealand Bridge Manual

In its current form, the Bridge Manual (Transit New Zealand 1994) includes only the following fragmented reference to deck joints, and provides little guidance on their use and selection:

Section 4: Analysis and Design Criteria

Section 4.11.4 Deck Drainage

Deck expansion joints shall be watertight unless specific provision is made to collect and dispose of the water.

Section 4.11.7 Expansion Joints

Expansion joints and the parts of the structure to which they are attached shall be designed so that the expansion joint can be installed after completion of the deck slab in the adjacent span(s).

Section 5: Earthquake Resistant Design

Section 5.5.1 Clearances

(b) Deck Joints

At temperature movement deck joints, clearance may be less than specified in (a), provided damage due to the design earthquake is limited to sacrificial devices (knock-up or knock-off devices), which have intentional weakness which permits minor damage to occur in a predetermined manner. In such circumstances the range of movement to be accommodated by the joint shall not be less than one quarter of the calculated relative movement under design earthquake conditions, plus long-term shortening effects where applicable, and one third of the temperature-induced movement from the median temperature position. Damage to deck joint seal elements due to the joint opening under this reduced earthquake movement is acceptable, provided mechanical damage is avoided.

The UK DoT Standards BD33/94 (1994a) and BA26/94 (1994b) do contain this kind of guidance although of course they are not related to New Zealand practice in bridge design and construction.

It is recommended that, to provide guidelines for the use and selection of expansion deck joints, an appendix should be included in the Bridge Manual, which refer to the UK DoT Standards. In order to relate these Standards to New Zealand conditions, reference notes would be incorporated. Guidelines to developing these notes are outlined below.

***Reference Notes for BD33/94** (UK DoT 11994a)*

- The need for Departmental-type approval, as set out in Annex A, does not apply in New Zealand;
- Buried joints are rare in New Zealand bridges because thinner road surfacings are used, and this fact should be stressed;
- All references to other British Standards and documents require review to ensure consistency with other Bridge Manual references;
- Section 4: Design; Section 5: Loads; Section 6: Movement – these sections of the Standard require review to ensure they are compatible with other Bridge Manual requirements;
- Section 8: Drainage – this section requires modification to suit New Zealand conditions.

***Reference Notes for BA26/94** (UK DoT 1994b)*

- Buried joints are rare in New Zealand because thinner road surfacings are used, and this fact should be stressed;
- Section 4.7 of the Standard indicates that the surfacing adjacent to an APJ should be not less than 100 mm thick. Practice in New Zealand is to use thinner joints but guidance on joint thickness will be dependant on any further investigation of these joints;

- Sections 5.2, 5.4: Subsurface drainage – these sections of the Standard should be modified to suit New Zealand conditions;
- Section 7: Inspection and Maintenance – requirements in this section of the Standard need to be compatible with guidance included in the Bridge Inspection and Maintenance Manual (1991).

5.2.2 Transit NZ Bridge Inspection & Maintenance Manual

The Bridge Inspection and Maintenance (BIM) Manual (Transit New Zealand 1991) considers the topic of deck joints under Section 3: Evaluation of Condition (Section 3.6.3: Deck Joints) and Section 4: Maintenance and Durability Enhancement (Section 4.4.2: Deck Joints).

Bruce (1999) recommended review of these sections in accordance with the findings of the research recorded in this report. These recommendations were incorporated in the June 2000 revision of the Bridge Inspection and Maintenance Manual. The recommendations were as follows:

Amendments made to Section 3.6.3, BIM Manual

- General revision of section to ensure that current joint technology is adequately covered;
- Joint nomenclature should be reviewed to conform with international convention;
- Faults common to particular joint types should be amended in accordance with section 4.3 of this report;
- The service history of asphaltic plug joints in New Zealand should be included.

Amendments made to Section 4.4.2, BIM Manual

- Guidelines for retrofitting of existing deck joints should be included. These should include criteria for the selection of appropriate replacement joint types by cross-referencing to UK DoT BD33/94 (1994a) and BA26/94 (1994b), and to the reference notes included in the appendices of the Bridge Manual.
- The preference to retrofit with sealed deck joints should be emphasised.

6. Conclusions

The following conclusions can be drawn from the findings of this work:

- Deck joint types in use in New Zealand are similar to those used in the UK and North America, except for buried joints which are designed for use with thick surfacing materials. These are uncommon in New Zealand.

- The best performing joint type used in both New Zealand and the UK are elastomer in metal runner joints. These should perform satisfactorily for extended periods of time with periodic replacement of seals.

- Some New Zealand road controlling authorities continue to install unsealed joints (e.g. open joints, sliding plate joints). These may lead to deterioration of the bridge substructure due to water leakage. Sealed joints are the preferred option for retrofitting existing unsealed joints when they become unserviceable.

- Correct installation of all joint types is critical to their long-term performance.

- Internationally, the clear trend is towards making bridges continuous and also to adopting integral abutments, where possible, to eliminate deck joints.

- Asphaltic plug joints are becoming more commonly used for retrofitting existing deck joints. Thinner surfacings used in New Zealand mean that, in some circumstances, these joints are installed with reduced dimensions compared to those originally developed in the UK. The general performance of these joints was rated as good by road controlling authorities. The thinner joints were performing adequately but further investigation is required to assess the limitations and long-term performance of these joints.

- The most common joint type used on New Zealand bridges are poured sealant joints. In general the local authority bridge stock includes a high proportion of small single-span bridges with no deck joints. Where they do exist, the joints are commonly small-movement, poured sealant joints. The greater proportion of multi-span bridges in the Transit New Zealand bridge stock results in use of a wider variety of deck joints.

- Road controlling authorities rated the overall performance of most deck joint types as acceptable. The exception was epoxy-nosed poured sealant joints, where the nosings are prone to cracking and debonding.

- Barnard & Cunninghame (1997b) concluded that the total cost of a deck joint is likely to be at least four times the direct cost of supply and installation, with traffic management and road user delay costs being the most significant item. Calculation of whole-of-life costs for joints would provide a basis for joint selection based on long-term performance but this may be difficult in New Zealand at present because appropriate data are lacking.

- The experience and knowledge of bridge consultants and road controlling authorities is a contributing factor to selecting a deck joint by its long-term performance or low initial cost. Guidelines for the selection and use of deck joints, which are made widely available to road controlling authorities and their consultants, should improve knowledge, and ultimately lead to better long-term deck joint performance by reducing the emphasis on lowest cost solutions.

7. Recommendations

Based on the findings of this work the following actions are recommended:

- With the increasing use of asphaltic plug joints in New Zealand, a more complete understanding is required of the international experience and local performance with this type of deck joint. A comprehensive study is recommended that encompasses material specifications, installation practices, and observed performance, to produce rational design guidelines appropriate to New Zealand conditions.

- Consideration should be given to the international trend towards bridges being made continuous, with integral abutments where feasible, and to investigate the implications of adopting this approach for New Zealand bridges.

- UK Department of Transportation Standards BD33/94 and BA26/94 provide the necessary guidelines for the use and selection of deck joints. Therefore an appendix should be included in the Transit New Zealand Bridge Manual which refer to the UK DoT Standards, and incorporate Reference Notes that relate the Standards to New Zealand conditions. Guidelines to developing these Notes are outlined in section 5.2.1 of this report.

- Joint selection should be based on long-term performance and not on initial cost. Whole-of-life cost calculations should be used to assist this process. However information available on joint maintenance expenditure in New Zealand is currently inadequate, and options for collecting joint maintenance expenditure data from road controlling authorities on an on-going basis should be investigated.

- Options for establishing a procurement system based on approval testing of deck joints and quality assurance of installation should be considered.

8. References

Barnard, C.P., Cunninghame, J.R. 1997a. Practical guide to the use of bridge expansion joints. *Transport Research Laboratory Application Guide 29.*

Barnard, C.P., Cunninghame, J.R. 1997b. Improving the performance of bridge deck expansion joints: Bridge Deck Expansion Joint Working Party Final Report. *Transport Research Laboratory Report 236.*

Bramel, B.K., Puckett, J.A., Ksaibati, K., Dolan, C.W. 1997. Asphalt plug joint usage and perceptions in the United States. *Transportation Research Record 1594:* 172-178. Transportation Research Board, National Research Council, Washington DC.

Bruce, S.M., Freitag, S.A, Hickman, W.E. 1999. Durability of concrete road bridges in New Zealand. *Transfund Research Report No.129.* 87pp.

Bruce, S.M. 1999. Guidelines for review of Transit New Zealand's Bridge Inspection and Maintenance Manual. *Central Laboratories Report 99-524508.00.* Opus International Consultants Ltd, Lower Hutt.

Burke, M.P. 1989. Bridge deck joints. *National Cooperative Highway Research Program Synthesis of Highway Practice 141.* Transportation Research Board, Washington DC.

Dahir, S.H., Mellott, D.B. 1988. Bridge deck expansion joints. *Transport Research Record 1118:* 16-24.

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Hong Kong Highways Department. 1993. Structures Design Manual for Highways and Railways. Hong Kong Government.

Manning, D.G., Witecki, A.A. 1981. Requirements for deck joints in highway structures. *ACI Publication SP-70 (1):* 291-309.

McGovern, M.S. 1999. A closer look at bridge expansion joints. Concrete Construction, Aberdeen Group.

Nicholas, C.J.A. 1987. Bridge maintenance survey results. *New Zealand Roading Symposium 4:* 847-855.

Ontario Ministry of Transportation. 1992. Ontario Highway Bridge Design Code. (OHBDC). 3rd Edition, Ontario.

Price, A.R. 1984. The performance in service of bridge deck expansion joints. *Transport and Road Research Laboratory Report 1104*. TRRL, Crowthorne, Berkshire.

Transit New Zealand. 1991. *Bridge inspection and maintenance manual*. 148pp. Transit New Zealand, Wellington, New Zealand.

Transit New Zealand. 1994. *Bridge manual*. Transit New Zealand, Wellington, New Zealand.

UK Department of Transportation (UK DoT). 1994a. Expansion joints for use in highway bridge decks. *UK DoT BD 33/94*. Her Majesty's Stationery Office, London.

UK Department of Transportation (UK DoT). 1994b. Expansion joints for use in highway bridge decks. *UK DoT BA26/94*. Her Majesty's Stationery Office, London.

UK Department of Transportation (UK DoT). 1995. Design for durability. *UK Dot BD57/95, BA57/95*. Her Majesty's Stationery Office, London.

UK Department of Transportation (UK DoT). 1996. The design of integral bridges. *UK Dot BA42/96*. Her Majesty's Stationery Office, London.

APPENDIX 1
INTERNATIONAL LITERATURE REVIEW

Summaries of Principal Documents Reviewed

Appendix 1 International Literature Review

New Zealand Literature

(a) Bloxham, M.J., Burnett, R.A., Mans, A.S. 1991. The In-Service Performance of Bridge Hardware. Murray-North Limited, Hamilton, March 1991. (Unpublished)

The findings of bridge inspections in the Waikato, Bay of Plenty and King Country areas are summarised. Included are observations on the performance on the various types of deck joints.

(b) Bloxham, M.J., Burnett, R.A., Mans, A.S. 1990. The In-Service Performance of Bridge Hardware (An Interim Report). *Transit New Zealand Road Research Unit Bulletin 84 (5)*: 67-79.

The interim findings of bridge inspections in the Waikato, Bay of Plenty and King Country areas are summarised. Included are observations on the performance on the various types of deck joints.

(c) North, P.J., Patterson-Kane, K.J., Bloxham, M.J. 1978. The Service Performance of Bridge Deck Joints Installed in Short Span Bridges. National Roads Board Road Research Unit Structures Committee Report for Project 47710, Dec. 1978.

53 selected bridges within 50 km of Hamilton were inspected and the condition of their deck joints reported. Joint types included were: compression seal, reinforced elastomeric seal (e.g. Transflex), elastomeric strip seal, steel plate, and poured sealant.

Results of a survey of Transit New Zealand and selected local authorities on the durability of concrete road bridges are reported. A postal survey was undertaken to identify common durability problems, how they were detected and further investigated, and the repair methods used and their effectiveness. Deck joint problems were reported to be particularly common in bridges of all ages, locations, and type.

(d) Nicholas, C.J.A. 1987. Bridge Maintenance Survey Results. *New Zealand Roading Symposium 4:* 847-855.

Results of a survey of Ministry of Works and Development offices and local authorities responsible for administering bridges are reported. The survey sought to record the nature of defects in the worst 10% of bridges under each authority's jurisdiction. Deck expansion joints were recorded to be defective in 28% of the bridges reported, the highest incidence of a defective item of all those categorised.

Australian Literature

(a) AUSTROADS (Association of State, Territory and Federal Road and Traffic Authorities in Australia). 1992: *AUSTROADS Bridge Design Code.*

Section 4 of this Code includes requirements for the design and installation of deck expansion joints for highway bridges. The associated commentary provides guidance on types of joint sealant material, but no guidance on deck joint types.

(b) AUSTROADS. 1991. Bridge Management Practice. *AUSTROADS Publication No. AP-13.*

A description of the commonly used forms of deck expansion joints is included, together with discussion of their typical problems and modes of failure. Limited guidance is also included on joint repair methods and materials.

(c) Davidson, G. 1994. Bridge Bearings and Expansion Joints, Recent Developments with Cost Implications. Bridges Essential to Our Economy. *Proceedings of the AUSTROADS 1994 Bridges Conference, Paper No. 45.*

Primarily focused on bridge bearings, the paper contains only brief comment on deck joints, suggesting that higher margins of safety are warranted and that many joints being installed do not comply with Bridge Design Code minimum requirements. Suppliers are being asked to warrant their product for periods of 5 – 10 years, to force them to add up-front quality in the interests of long-term performance and net lower life cycle costs.

United Kingdom Literature

(a) Barnard, C.P., Cunninghame, J.R. 1997a. Practical Guide to the Use of Bridge Expansion Joints. *Transport Research Laboratory Application Guide 29.*

This report constitutes a guide to the selection, specifying, procuring, installing and maintaining of deck expansion joints to achieve good performance. Included is a rating of the performance of different joint types against a list of operational conditions, and a summarisation of advantages, disadvantages and commonly reported defects of the different joint types.

(b) Barnard C.P., Cunninghame, J.R. 1997b. Improving the Performance of Bridge Deck Expansion Joints: Bridge Deck Expansion Joint Working Party Final Report. *Transport Research Laboratory Report 236.*

The project report encompassed a survey of the majority of UK highway bridge owners, to gain a snapshot of the current situation on deck joint performance and to identify the problem areas.

Each aspect of joint selection, installation, performance and maintenance was studied, and a whole-of-life cost study undertaken. The project found that the total cost of an expansion joint is far greater than its initial installation cost and that most failures were caused by traffic loading, faulty installation, poor detailing, or small movements (daily thermal cycles and /or traffic induced movement). Therefore the whole range of service conditions need to be taken into account when selecting a joint type for a particular application. A change in procurement practices to one based on the whole-of-life costs of deck joints is recommended.

(c) United Kingdom Department of Transportation (UK DoT). 1994a. Expansion joints for use in highway bridge decks. *UK DoT BD 33/94*, Her Majesty's Stationery Office, London.

A Standard which sets out the loads and movements to be used for the design of bridge deck expansion joints, and the requirements for their selection, and Departmental type approval. This is a scheme administered by the Highways Agency under which proprietary joint systems are classified by joint type and approved for use based on a detailed specification of the system and installation procedures and satisfactory trial performance.

(d) United Kingdom Department of Transportation (UK DoT). 1994b. Expansion joints for use in highway bridge decks. *UK DoT BA26/94,* The Department of Transport et al., Her Majesty's Stationery Office, London.

A document providing guidance on the selection and installation of expansion joints in highway bridge decks, together with advice on the commonly used types of joint. It includes a table providing a rating of joint type performance against factors affecting performance.

(e) United Kingdom Department of Transportation (UK DoT). 1994c. Waterproofing and surfacing of concrete bridge decks. *UK Dot BA47/94, UK DoT BD47/94*. The Department of Transport et al., Her Majesty's Stationery Office, London.

Two related documents, a Standard (UK DoT BD 47/94) providing requirements, and an Advice Note (UK DoT BA 47/94) providing information, respectively, for the design, materials and workmanship for the waterproofing and surfacing of the concrete decks of highway bridges. These documents provide a setting within which to view the application of deck expansion joints in UK practice.

(f) United Kingdom Department of Transportation (UKDoT). 1995. Design for durability. *UKDoT BD57/95, BA57/95.* Her Majesty's Stationery Office, London.

Two related documents, a Standard (UKDoT BD57/95) providing requirements, and an Advice Note (UKDoT BA57/95) providing information, respectively, for the design of bridges in order to improve their durability. These identify deck joints as a primary source of durability problems and require or promote the adoption of continuous bridge structures wherever possible.

(g) United Kingdom Department of Transportation (UKDoT). 1996. The design of integral bridges. *UKDoT BA42/96.* Her Majesty's Stationery Office, London.

An Advice Note providing guidance on the design of continuous bridges with integral abutments.

(h) Lee, D.J. 1994. *Bridge bearings and expansion joints.* 2nd Edition, E & FN Spon, London.

This book contains a 23-page section devoted to deck joints, subdivided into categories of small, medium and large movements, and longitudinal joints. It presents a general discussion of the types of joint in common use in the UK.

(i) Price, A.R. 1984. The performance in service of bridge deck expansion joints. *Transport and Road Research Laboratory Report 1104.* TRRL, Crowthorne, Berkshire.

This report summarises the findings of seven years of investigations into the performance of bridge deck joints in the UK, covering installation practice, joint design and materials used, the nature of deterioration and factors influencing performance. A wide range of factors influenced performance. It was found that to achieve long-term satisfactory performance, the design, choice of joint, installation procedures, and factors influencing the service conditions need to be considered very carefully. The report's presentation tends to be generalised.

(j) Price, A.R. 1983. The performance of nosing type bridge deck expansion joints. *Transport and Road Research Laboratory Report 1071.* TRRL, Crowthorne, Berkshire.

This report summarises the findings of seven years of investigations into the performance of nosing type bridge deck joints in the UK, covering installation practice, nosing design and materials used, the nature of deterioration and factors influencing performance. The factors were evaluated and graded according to the severity of their effect on the long-term serviceability of the nosing. Traffic, materials used, workmanship, installation conditions, and the condition of the substrate were the key factors but often it was a complex combination of factors which caused premature failure.

North American Literature

(a) AASHTO (American Association of State Highway and Transportation Officials). 1996. *Standard Specification for Highway Bridges.* 16th Edition.

Section 16 presents a specification for the supply and installation of bridge deck joint seals, focused primarily on the elastomeric compression seal and elastomeric strip seal type of joints.

(b) AASHTO. 1994. *AASHTO LRF Bridge Design Specifications (1994).* 1st Edition.

Section 14 of these specifications includes design requirements, advice and commentary for the design of highway bridge expansion joints. Considerations for specific joint types are outlined.

(c) Ontario Ministry of Transportation. 1992. *Ontario Highway Bridge Design Code (OHBDC).* 3rd Edition. Ontario.

Section 4 of the code specifies design requirements for highway bridge expansion joints. The accompanying commentary cites a list published by the Ministry of Designated Sources in which proprietary joints meeting the code requirements are listed and classified. Guidance is included on joint assembly, installation and anchorage.

(d) Manning, D.G., Witecki, A.A. 1981. Requirements for deck joints in highway structures. *ACI Publication SP-70 (1):* 291-309.

The rationale and requirements for deck joints set out in the Ontario Highway Bridge Design Code are described. Comment on procurement options is also included.

(e) Burke, M.P. 1989. Bridge Deck Joints. *National Cooperative Highway Research Program Synthesis of Highway Practice 141.* Transportation Research Board, Washington DC.

This synthesis focuses specifically on the development, design, construction, and evaluation of deck joints for bridges; the experience over the previous two decades in the development of various types of elastomeric seals; the development of integral construction; and some of the developments in joint waterproofing and joint drainage management. This is a comprehensive report drawing on an extensive list of references.

(f) Dahir, S.H., Mellott, D.B. 1988. Bridge deck expansion joints. *Transport Research Record 1118:* 16-24.

The paper reports a study of the characteristics and field performance of modular expansion joint systems, metal-reinforced elastomer expansion dam systems, and gland-type expansion dam systems. Results are summarised, and recommendations made on continued use of some systems, including neoprene seals for small movements (<50 mm), strip seals for intermediate movements (up to 100 mm), and finger dams with neoprene troughs for large movements (>100 mm).

(g) Hill, J.H., Shirolé, A.M. 1984. Bridge joint systems – a performance evaluation. *Transportation Research Record 990:* 1-4. Transportation Research Board, National Research Council, Washington DC.

Conclusions drawn from a performance evaluation of more than 2000 bridge deck joints in Minnesota are presented. The paper focuses on common problems, the joint types particularly prone to these problems, and remedial actions. A summary is provided of joint types, their advantages and disadvantages, typical problems, and unit cost.

(h) Weisgerber, F.E., Minkarah, I.A., Malon, S.R. 1988. Observations from a field study of expansion joint seals in bridges. *Transportation Research Record 1118:* 39-42. Transportation Research Board, National Research Council, Washington DC.

A field study of 360 expansion joint seals in Ohio highway bridges is reported. An analysis of the performance of the 3 generic seal types: strip seals, compression seals, and steel reinforced seals is presented. By the nature of the study, only surviving joints are included in the study, and within the generic types, no distinction is made between different brands. The outcome of the study was essentially inconclusive.

(i) Bramel, B.K., Puckett, J.A., Ksaibati, K., Dolan, C.W. 1997. Asphalt plug joint usage and perceptions in the United States. *Transportation Research Record 1594:* 172-178. Transportation Research Board, National Research Council, Washington DC.

The results of a survey of 50 state departments of transportation to assess use, perceptions, and installation guidelines, are reported. All 50 states responded.

Other Literature

(a) *Specifications for Highway Bridges*, Japan Road Association:

- Part I : Common Specifications & Part III : Concrete Bridges, March 1984
- Part II : Steel Bridges, March 1987
- Substructures (1966 – 1980), 1981
- Part V : Seismic Design, February 1990

An English language translation of the Japanese bridge design specifications. Contains only one very general paragraph related to deck expansion joints.

(b) Personal communication with Dr A. Mori, Japan Engineering Consultants, Japan.

Dr Mori indicated that the Japanese "Specification for Highway Bridges" had been revised in 1996, but that it contained no valuable information on deck joints. Deck joints are prescribed in the "Manual of Expansion and Contraction Joints for Bridges", believed to be published only in Japanese. For multi-span bridges exceeding 50 m in length, continuous superstructures have generally been favoured, for reasons of seismic security.

(c) Hong Kong Highways Department. 1993. *Structures Design Manual for Highways and Railways*. Hong Kong Government.

The Hong Kong road structures design standard includes design loading and functional requirements for deck movement joints, the prescription of filled or buried joint types for movements of less than ±5 mm and proprietary joints for greater movements, and the selection of suppliers and installers.

APPENDIX 2

SURVEY OF ROAD CONTROLLING AUTHORITIES

SURVEY
PERFORMANCE OF BRIDGE DECK EXPANSION JOINTS

This survey has two principal aims:

- To assess the performance of different bridge expansion joint systems
- To identify a range of bridges suitable for inspection which represent failures and successes of expansion joints of different types. These inspections will form the next stage of this research project.

Please use additional pages as necessary to elaborate on any comments

1. How many bridges fall within the jurisdiction of your office Local Authority/TNZ Regional Office? (a bridge is defined as a structure having a waterway area exceeding 3.5m^2).

   ____

2. What percentage of the bridge stock administered by your office includes deck expansion joints in the bridge design?

   0-10% ☐

   10-20% ☐

   20-30% ☐

   30-40% ☐

   40-50% ☐

   50-60% ☐

   60-70% ☐

   80-90% ☐

   90-100% ☐

3 On how many bridges has your office had bridge deck expansion joints installed in the past 10 years?

None	< 5	5-10	10-20	20-30	30-40	40-50	>50
☐	☐	☐	☐	☐	☐	☐	☐

4 What is the total number of bridge deck expansion joints your office has had installed in the past 10 years?

None	< 5	5-10	10-20	20-30	30-40	40-50	>50
☐	☐	☐	☐	☐	☐	☐	☐

5 Of these expansion joints how many were installed on

a) Existing bridges due to poor performance or failures of the previous deck joints

None	< 5	5-10	10-20	20-30	30-40	40-50	>50
☐	☐	☐	☐	☐	☐	☐	☐

b) New Bridges

None	<5	5-10	10-20	20-30	30-40	40-50	>50
☐	☐	☐	☐	☐	☐	☐	☐

6 Which of the following generic types of bridge deck joints have you installed on your bridges in the past 10 years? If possible please also indicate joint brand and model.

(Refer to Appendix A at the back of this document to confirm joint nomenclature)

	Tick Appropriate Box	Joint brand and model
Open joint	☐	
Sliding plate joint	☐	
Poured sealant joint (e.g. Fosroc Colpor 200)	☐	
Epoxy nosed poured sealant joint	☐	
Buried joint	☐	
Cantilever finger plate joint	☐	
Asphaltic plug joint (e.g. Thormajoint, Wabocrete EBJ)	☐	
Compression seal/cellular seal joints (e.g. Wabo compression seals, Miska compression seals)	☐	
Reinforced elastomeric joint (e.g. Waboflex, Transflex)	☐	
Elastomeric single seal in metal runners (e.g. Miska, Wabo, Honel)	☐	
Other joint types	☐	please specify type

(NB joint types designed to accommodate large movements >125mm (e.g. Multiple rubber seals in metal runners; some cantilever finger plate,comb or tooth joints) are considered to be outside the scope of this investigation).

7 Please rate the performance of known deck joints and describe the typical problems encountered (use a separate page if necessary).

	Good	Average	Poor	What are the typical problems encountered with each of these joint types
	Tick appropriate box			
Open joint				
Sliding Plate joint				
Poured sealant joint				
Epoxy nosed poured sealant joint				
Buried joint				

Cantilever finger plate joint				
Asphaltic plug joint				
Compression Seal/cellular seal joint				
Reinforced elastomeric joint				
Elastomeric single seal in metal runners				
Other joint types (please specify type)				

8 What is the typical serviceable life for bridge deck joints systems your office have used?

If a particular joint type has been in service for less than 30 years and is performing well please indicate the time in service and tick the "still in service" box.

Serviceable life (years)

	0-5	5-10	10-15	15-20	20-30	>30	Still in Service
Open Joint	☐	☐	☐	☐	☐	☐	☐
Sliding plate joint	☐	☐	☐	☐	☐	☐	☐
Poured sealant joint	☐	☐	☐	☐	☐	☐	☐
Epoxy nosed poured Sealant joint	☐	☐	☐	☐	☐	☐	☐
Buried Joint	☐	☐	☐	☐	☐	☐	☐
Cantilever finger plate joint	☐	☐	☐	☐	☐	☐	☐
Asphaltic plug joint	☐	☐	☐	☐	☐	☐	☐
Compression seal/cellular Seal joint	☐	☐	☐	☐	☐	☐	☐
Reinforced elastomeric Joint	☐	☐	☐	☐	☐	☐	☐
Elastomeric single seal In metal runners	☐	☐	☐	☐	☐	☐	☐
Other joint types	☐	☐	☐	☐	☐	☐	☐

9 The next stage of this research involves inspection of a range of bridges representing failures and successes of bridge joints of different types. Could you please nominate individual bridge structures which would be suitable candidates for these inspections.

Bridge Name And location	Joint type Brand and model	Year Installed	Success / Failure Any known problems and possible causes

10 Please provide any further comment on the performance of bridge deck expansion joints.

DETAILS OF PERSON COMPLETING QUESTIONNAIRE

NAME : ______________________

POSITION : ______________________

ORGANISATION : ______________________

EXPERIENCE OF RESPONDENT

____
____
____
____
____
____
____
____

(Please provide details of the source of information used to answer the survey questions. Please indicate the how long you, or others who had input to the responses, have been involved with this bridge stock. If you are acting as a consultant to a bridge owner please indicate how long you have held that contract.)

Please return by Friday **9 APRIL 1999** in the stamped self-addressed envelope to:

Opus International Consultants Ltd
Central Laboratories
P O Box 30845
LOWER HUTT

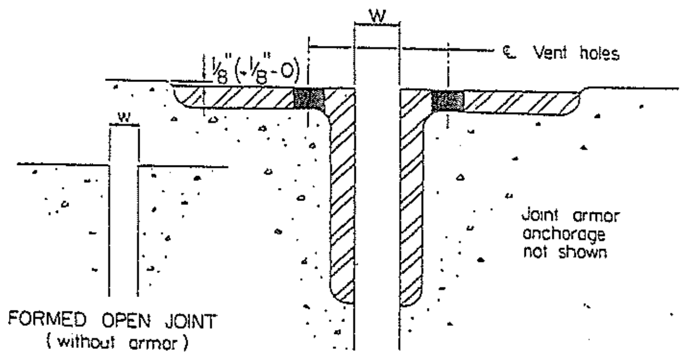
ATTENTION : SHELDON BRUCE

If you have any quesitons about the questionnaire, please contact

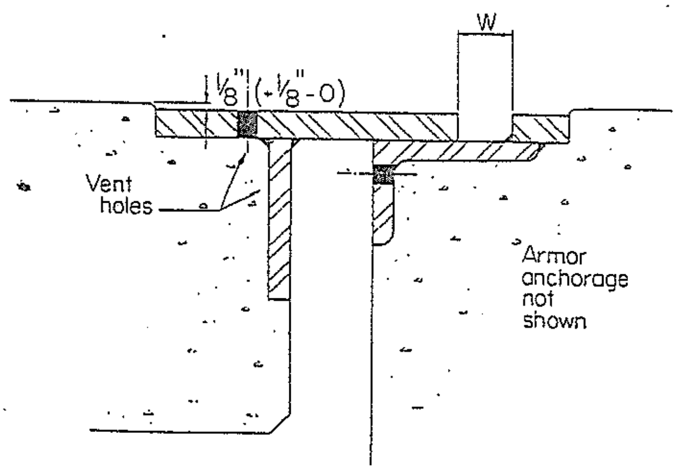
Sheldon Bruce
Phone: (04) 5683-119
Fax : (04) 5683-169

APPENDIX A
NOMENCLATURE FOR
BRIDGE DECK EXPANSION JOINTS

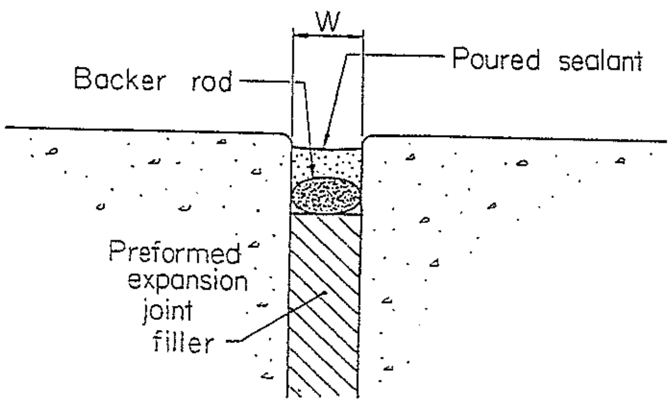
Open Joint



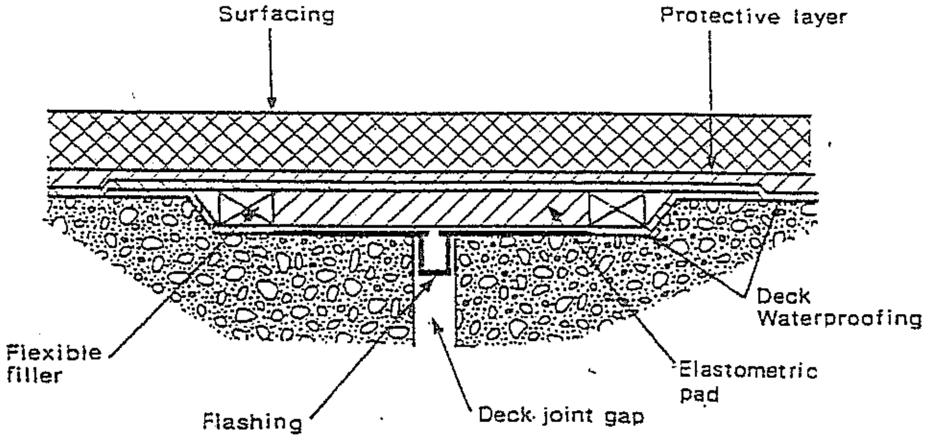
Sliding Plate Joint – gap is bridged by a metal plate, fixed on one side of the gap and sliding on supporting metalwork on the other side.



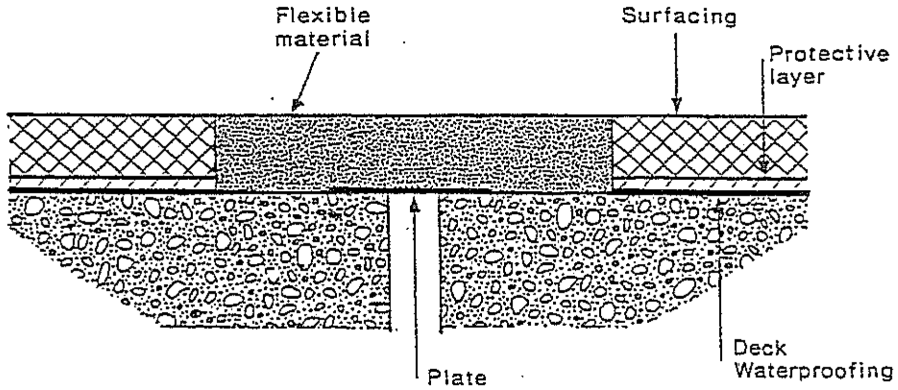
Poured Sealant Joint



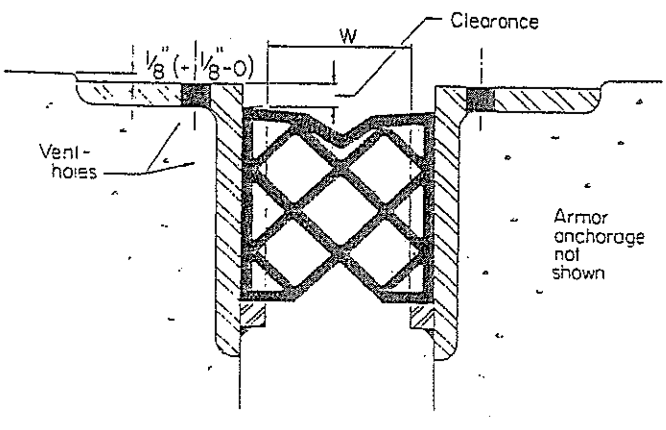
Buried Joint – deck surfacing is carried continuously across the top of the joint



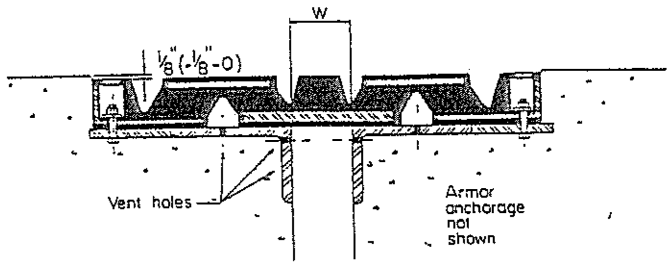
Asphaltic Plug Joint, asphaltic concrete joint, elastomeric concrete joint – the primary material forming both the nosing and bridging over the joint is an aggregate bound with a binder of elastomeric material, commonly a rubberised bitumen with filler material, but may alternatively be composed of a proprietarybinder of resin and hardeners filled with materials such as silica sand and lime.



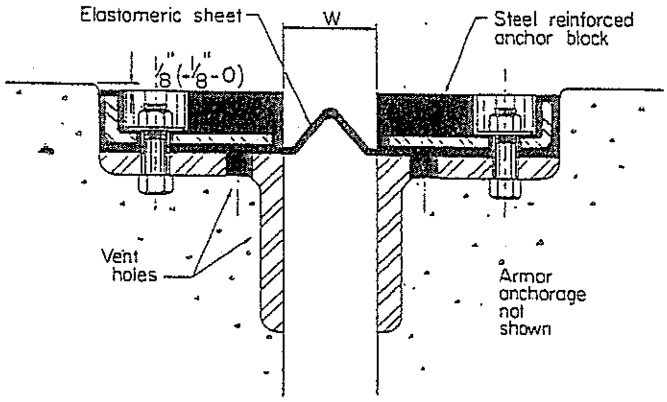
Compression Seal/Cellular Seal Joints – a cellular rubber element positioned in the joint gap. In the case of a compression seal joint the rubber seal is element is compressed between the nosings. For a cellular seal joint retention of the seal element does not rely on compression.



Reinforced elastomer joint - there are two basic variations of this joint type, one where the gap is bridged by a reinforced elastomeric plank, and the other where the joint is bridged by a thin elastomeric sheet anchored on either side of the gap by reinforced elastomeric block nosings.

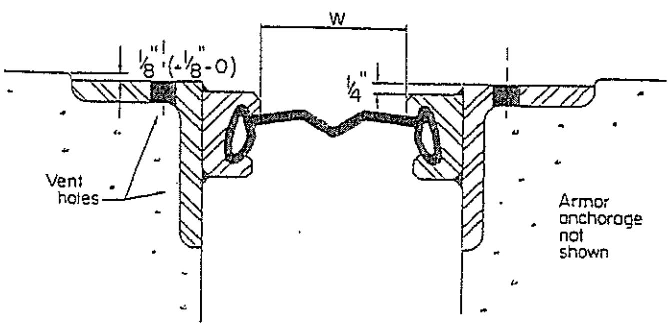


Reinforced Elastomeric Plank Seal

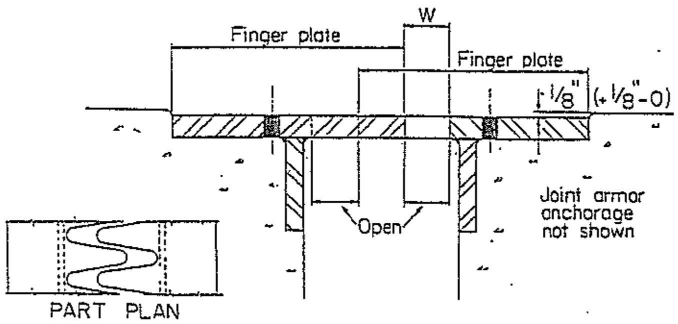


Elastomeric Sheet Seal

Elastomeric single seal in metal runners – metal extrusions fixed to the edge of the nosings anchoring a rubber membrane seal, bridging the gap.



Cantilever Finger – Plate Joint – steel plate or teeth elements cantilevering from either side of the joint and interleaved



Cantilever Finger-Plate Joint

APPENDIX 3

SURVEY OF DECK JOINT SUPPLIERS

TRANSFUND RESEARCH : PERFORMANCE OF BRIDGE DECK EXPANSION JOINTS

GENERIC LETTER TO JOINT SUPPLIERS

The Performance of Bridge Deck Expansion Joints

Opus International Consultants Limited have been appointed by Transfund New Zealand to undertake a research project into the performance of bridge deck expansion joints. The focus of the project is on bridge deck joint types that are in current common use in new bridge construction and bridge retrofit. The project encompasses:

- a literature survey to identify current international best practice,
- a survey of joint suppliers and a selected sample of Transit New Zealand Regional Offices and Territorial Authorities administering bridges to identify joints installed in the last 10 years, and
- inspection of a sample of the joints to observe both successes and any problems, and in the case of problems to investigate the causes of them.

We understand your company to be, or have been, a supplier of bridge deck expansion joints. We would like to request from you, supply of up-to-date catalogues or brochures of the deck joint products you supply, and advice of your principal sales consultant for these products.

In respect to each different generic type of deck joint you supply, we would appreciate advice of:

- the typical supply cost for the joint
- the typical installation cost for the joint
- in a retrofit situation, the typical time required for preparation of the structure and installation of the joint (to provide a guide to the extent of traffic disruption involved)
- the service life expected of the joint

In respect to deck joints your company has supplied or installed in the last 10 years, we would be grateful for your assistance with supply of as much of the following information as is practicable:

- name of the bridge, and location (road or highway, nearest town), on which joints have been installed
- name of the bridge owner
- brand name, model, and type of joints installed
- number of joints installed on each bridge, their length, and supply and installation cost
- the date (month and year) of joint installation
- any problems experienced with the joints, and comment on possible causes

Blank tables are appended to assist with compilation of this data.

The objective of the research is to report on the performance of deck joints in New Zealand bridges and to provide guidelines for the use of different generic joint types in new and existing bridges.

In anticipation, thank you for your assistance with this project. As our surveying of bridge owners will draw on responses received from joint suppliers, it would be very much appreciated if we could receive your response prior to Christmas.

Yours sincerely
Opus International Consultants Limited

Donald Kirkcaldie

TRANSFUND RESEARCH : THE PERFORMANCE OF BRIDGE DECK EXPANSION JOINTS
DATA ON JOINT INSTALLATIONS IN THE LAST TEN YEARS

SUPPLIER :

Bridge Name & Location	Bridge Owner	Joint Brand, Model & Type	No. of Joints Installed, & Total Length	Year & Month Installed	Contract Amount	Any Known Problems & Possible Causes

TRANSFUND RESEARCH : THE PERFORMANCE OF BRIDGE DECK EXPANSION
TYPICAL DATA FOR GENERIC JOINT TYPES

SUPPLIER :

Generic Joint Type	Typical Supply Cost ($/m)	Typical Installation Cost ($/m)	Typical Retrofit Structure Preparation & Joint Installation Time (hours/m)	Expected Joint Service Life (Years)

APPENDIX 4

SUMMARY OF DECK JOINT INSPECTION

BRIDGE	LOCATION	YEAR OF CONSTRUCTION	DECK JOINT TYPES AND HISTORY	DECK JOINT PERFORMANCE
Thorndon Overbridge	SHIN 987/2.25	1973	Original joints compression seals with metal angles. Joints replaced 1990-1992 with 500mm W x 50mm D Prismo Asphaltic Plug Joints (APJ). Deck resealed with friction course. 60,000 to 70,000 vehicles/day	Joints concealed by friction course seal. Longitudinal cracking in seal at middle and edges of joints. Edge cracking suggests some debonding at joint nosing. Joints waterproof. Overall joint performance good after 7-9 years in service.
Aotea Quay Flyover	Wellington City	1930's	Original joint types unknown. Split pier joints (originally poured sealant?) retrofitted with 300mm W x down to 25mm D Techniflex APJ. Expansion joints retrofitted with compression seals with PMB type nosings. Joints skew to carriageway. No surfacing over joints. High traffic volumes.	APJ's in poor condition due to shoving and weaving of joint filling material in wheel paths. Joint cracking and failure in wheel paths. Skew of joint to traffic and joint thickness (25mm) may be contributing factors. Joints not waterproof. Compression seal joint in good condition.
Mungavin Overbridge	SHIN 969/4.36	1989	Felspan T20 CS Elastomeric Sheet Seals with concrete nosings. 1200mm long plank units with 35mm sheet sealed gap. Moderate traffic volumes.	Joints in satisfactory condition. Concrete noising breaking along back edge of plank unit increasing the possibility of joint leakage. Wear of plank units where installed slightly below carriageway surfacing level. Joints waterproof.
Mungavin Bridge	Porirua City		Original joint types unknown. Expansion joints retrofitted with Waboflex reinforced elastomeric plank seals. 1500m long units. Moderate traffic volumes.	Joints in satisfactory condition. Deterioration of nosings resulting in significant spalling and high probability of water leakage. Some nosings retrofitted with PMB type nosings (about 100mm wide) and are performing adequately.
Mungavin Duplication	Porirua City	1998	Miska BJ2 elastomer in metal runner joints (EMR). Joints not carried into footpath – carriageway only. Moderate traffic volumes.	Joints in good condition. Signficant volume of debris built up in joint above rubber seal. Watertight beneath carriageway.
Keneperu Stream Bridges	Porirua City & SHIN 969/4.10	1989	Miska BJ1 EMR joints with shredded rubber infill material in hold down bolt cavity. Miska BJ2 joint used to replace one BJ1 joint due to poor installation level. Friction course seal except for intermediate poured sealant joints bridged with 500mm W x 40mm D asphaltic concrete (AC) overlay. Moderate traffic volumes.	EMR joints in good condition. Build up of debris in joint cavity. AC overlay over poured sealant joints showing central longitudinal cracking although overlay has probably improved rideability.

BRIDGE	LOCATION	YEAR OF CONSTRUCTION	DECK JOINT TYPES AND HISTORY	DECK JOINT PERFORMANCE
Paremata Harbour Bridge	SHINM 953/15.41	1936	Original split pier joints with poured sealants. Retrofitted in 1995 with Prismo APJ. Range between 300mm and 150mm wide depending on joint. Thickness unknown. High traffic volumes.	All joints performing satisfactorily. No cracking in joint material. Joints waterproof.
Akatarawa Bridge B1/1	Upper Hutt City Council	1980	Original EMR joints. Steel angle at carriageway level. Concrete nosings. Low traffic volumes.	Joints in good condition. Build up of debris in joint cavity. Waterproof.
Totara Park Bridge	Upper Hutt City Council	1967	Two end expansion joints retrofitted with sliding plates. Joints over piers retrofitted with Prismo APJ (500mm wide). Moderate traffic volumes.	Sliding plate joints in poor condition. Hold down bolts loose and proud. Plates loose. Joints leaking. One plate overlaid with thin sheet of PMB to improve rideability but this has stripped off. APJ's in satisfactory condition. Some tracking in wheel paths and minor longitudinal cracking. Joint pulled away from adjoining seal along one edge. Joint waterproof.
Kennedy-Good Bridge	Hutt City	1970 s	Four EMR joints. Five intermediate joints each consisting of two poured sealant (Thioflex?) joints either side of hammerhead upstand. Moderate traffic volumes. Deck not sealed.	EMR joints in good condition. Waterproof. Joint cavity full of debris. Poured sealants in good condition. Waterproof. Minor debonding at carriageway level.
Melling Bridge	Hutt City	1957	Mid bridge expansion joint is original EMR joint. Intermediate joints are poured sealant. 400mm wide AC overlay over one poured sealant joint to improve rideability. AC deck seal. High traffic volumes.	EMR joint in poor condition. Joint installed above carriageway level causing vehicle impact and poor rideability. Epoxy/bitumem(?) nosing loose and spalling exposing hold down bolts and plate. Rubber seal intact. Cracking in AC seal above all poured sealant joints giving poor rideability. Joints probably leaking.
Ewen Bridge	Hutt City	1997	Two very large expansion joints fitted with Waboflex SR6.5 reinforced elastomeric plank joints. High traffic volumes.	Joints in good condition. Waterproof. Steel angles forming nosings loose in some areas. Edge planks rotate under traffic which suggests some debonding of bedding material. Joints may be slightly proud of carriageway although is probably acceptable..

BRIDGE	LOCATION	YEAR OF CONSTRUCTION	DECK JOINT TYPES AND HISTORY	DECK JOINT PERFORMANCE
Manuherikai River Bridge	SH85 120/0.00	1960	Technics PMB 403 APJ's 30mm wide. Low traffic volumes. Chipseal over joints.	From photograph. Joints showing some deterioration. Tracking in wheel paths and longitudinal cracking both at joint edge and within joint itself. Very dry climate so waterproofness a minor issue. Cold winter temperatures may be a factor in performance.
Waitaki River Bridge	SH1S 569/0.00	1956	Retrofit of poured sealant joints. Pliastic 77 poured sealant placed over flexcell backer. Multi-span bridge.	From photograph. Some joints performing well. Others have failed possibly due to greater movement. Failures involve flexcell backing pushing through sealant.
Waipori River Bridge	SH1S 729/13.39	1961	13 span bridge with short (~ 12 m) spans. Poured sealant joints retrofitted with Pliastic 77 poured sealant joints. Low traffic volumes.	Joint performance poor. Sealant intact in some cases but in many joints sealant has been removed and backing rods are visible. Joints filled with debris. Chipseal surface has broken away from joint leaving a gap of up to 70mm promoting noise and poor ride quality. Some joint leakage.
Taieri River Bridge	SH1S 729/6.50	1965	30 span bridge with short (~ 12m) spans. Poured sealant joints retrofitted with poured sealant, Pliastic 77 joints. Joints chased out to 45mm and sealant placed over metal cap. Low traffic volumes. Sealant placed up to chipseal level. Low traffic volumes.	Joint performance poor. Sections of some joints performing OK but sealant removed and metal cap loose particularly in wheel paths. Chipseal spalling at joint edges promotes noise and poor ride quality.
Glen Overbridge	SH1S 707/1.07	1987	Two expansion joints fitted with Felspan elastomeric sheet seals. 100mm wide planks, 30mm joint gap. Chipseal surfacing. Moderate traffic volumes.	Rubber membranes on both joints punctured due to build up of chips on joint cavity or chipsealing through joint. Failure under wheel loads. Both joints leaking.
King Edward Street Overbridge	SH1S 707/0.40	1979	Two EMR joints. Metal nosings. 20mm movement gap. One joint built up on one side with 20mm plate due to differential settlement of bridge. Moderate traffic volumes.	Both joints in good condition. Joint cavity filled with debris and chips. Joint may have been chipsealed over. Watertight.

BRIDGE	LOCATION	YEAR OF CONSTRUCTION	DECK JOINT TYPES AND HISTORY	DECK JOINT PERFORMANCE
George Street Overbridge	SH1S 700/3.08	1957	Sliding plate joints with 23mm movement gap. Moderate traffic volumes.	Joint functioning adequately. Joint cavity filled with debris. Joint is some 24mm below seal level which promotes poor rideability. Gap above joint filled with bituminous material (PMB?) to improve ride but most of this has been removed by trafficking.
Allanton Bridge (Taieri River)	Dunedin City	1970's	Multiple span bridge. All joints fitted with Transflex C120 reinforced elastomeric plank joints. Joints 110mm wide. Relatively small movement. Low traffic volumes.	All joints in good condition. Waterproof.
Fitzgerald Avenue Bridge	Christchurch City	1960's	Three expansion joints fitted with compression seals with epoxy nosings. Joint width 30mm. Each nosing 150mm – 200mm wide. Moderate traffic volumes	Compression seals appear in good condition. Epoxy nosings in poor condition. Cracked at 600mm – 1000mm intervals along length and cracking between deck seal and nosing bandaged with PMB. Nosing deterioration likely to promote leakage although joints currently watertight.
Heathcote River Bridge	SH75 0/1.13	1973	Original poured sealant joints failed. Joints retrofitted with Prismo APJ s 500mm wide. Moderate traffic volumes.	Joints in good condition. Only deterioration is short longitudinal crack in middle of joint on shoulder, ie out of trafficked area. No other deterioration.
Horotane Valley Overpasses	SH74 17/0.73	1963	All joints retrofitted with Prismo APJ's in 1988. Decks recently resealed with friction course. Moderate traffic volumes.	Joints in service for 11 years and have performed well. Joints concealed by friction course – some minor longitudinal cracking at joints reflecting through. Staining on pier cap of one structure suggests some leakage may be occurring but otherwise waterproof.
Port Hills Road Overpasses	SH74 17/0.53	1963		
Heathcote River (Opawa)	SH74 12/1.79	1990	Two expansion joints fitted with compression seals with 200mm wide epoxy nosings. Chipseal build up at joints promoted poor rideability. Rideability addressed by sealing over joint area (7m long) with 30mm thick AC overlay. Moderate traffic volumes.	Compression seals concealed by AC overlay but appear to be functioning adequately. No signs of leakage. Epoxy nosing visible at deck edge is cracked laterally. AC overlay has promoted better ride quality but gap at joint now open to up to 100mm wide and rideability is deteriorating. AC overlay has provided short term improvement in rideability.

BRIDGE	LOCATION	YEAR OF CONSTRUCTION	DECK JOINT TYPES AND HISTORY	DECK JOINT PERFORMANCE
Raceway Overpass	SH73 0/3.65	1980	Two EMR joints. 40mm metal nosings with 70mm gap. Moderate – high traffic volumes.	Both joints in good condition. No leakage. Joint gaps both filled with chip and other debris. Joint detail include upstand at edge of deck which prevents leakage at bridge edge. Joints relatively noisy due to width of joint gap.
Lincoln Road Overpass	SH73 0/3.44	1980	Two EMR joints. Original nosing 100mm wide. 40mm joint gap one joint 70mm gap at other joint. Additional 50mm high metal section welded to top of nosing to raise joint gap to new seal level. Moderate – high traffic volumes.	Both joints in good condition. No leakage. Both joint gaps filled with debris. Additional steel section added to metal angles functioning well. Relatively noisy.
Waimakariri River Bridge	SH1S 327/0.00	1967	Multi-span bridge with ~ 20m spans. Relatively small movement at joints. Compression seals (30mm wide) with metal angle nosings. Metal angles built up to seal level with 30 x 30mm steel section welded to top. Moderate traffic volumes.	Functioning well. No leakage through joints. Some staining on deck soffit at joints along outer edge of deck.
Cam River Bridge	SH1S 317/3.07	1972	Four poured sealant joints. Retrofit of running surface with AC overlay about 15 years ago. Chipseal since then. Light traffic volumes.	Joints not visible due to carriageway seals but intermittent cracking in seal above each joint. Leakage staining on pier caps suggests joints may not be watertight.
Ashley River	SH1S 311/0.00	1937	Retrofit of deck joints carried out 5 years ago. Split pier joints at every 3rd pier replaced with compression seals. Two construction joints between split piers replaced with poured sealants. Low traffic volumes.	Access onto carriageway difficult. Inspection of bridge substructure showed no signs of leakage. Joints functioning well.
Kaiapoi River Bridge	SH1S 317/5.83	1970	Compression seals (30mm wide) with epoxy nosings (250mm wide). Chipseal carried partially over nosings. Moderate traffic volumes.	Compression seals in good condition. Nosings cracked at regular intervals (~ 600mm centres). Cracking sealed with PMB bandages. Joints appear to be watertight. Joints noisy and subject to vehicle impact due to placement of nosing above seal level and slightly potholing of chipseal behind nosing.

BRIDGE	LOCATION	YEAR OF CONSTRUCTION	DECK JOINT TYPES AND HISTORY	DECK JOINT PERFORMANCE
Cam Road Underpass	SH1S 317/5.51	1969	Two sliding plate joints at abutments. Original. Low traffic volumes.	Sliding plate joint gap filled with chips and debris. Joints functioning adequately. Rideability acceptable. Both joints leaking over abutment sill. Beams unaffected by leakage due to separation from abutment sill by 70mm thick rubber bearings.
Mohaka Bridge	SH5 220/0.00	1962	Problems encountered with retrofit using Prismo APJ. Final solution involved recasting of deck ends with integral nosings and spans tied together. Poured sealant joint (Colpor).	Description only. Preparation for installation of Prismo APJ involved cutting out deck to achieve required joint thickness. Cutting resulted in breaking end off 150mm thick deck. Recasting of deck ends and replacement with poured sealant joint but these joints have failed and leakage is occurring.
Waitangi Ngaruroro Bridge	SH2 650/9.02	1965	Retrofit of 9 joints in 1990 with Prismo APJ s. 500mm wide x 70mm thick. To achieve joint thickness deck cut down 50mm (reinforcing steel exposed). Moderate traffic volumes.	Prismo joints performing well after 9 years in service. Joints concealed by chipseal but generally no cracking at centre of joints. Slight lineation visible at edge of some joints. No apparent leakage. In three locations in outer wheel path joints show compression, shear failure and longitudinal cracking. Possible causes are original poor area of joint, high traffic loads of initial disturbance of surface due to wheel locking.
Clive Bridge	SH2 661/0.25	1954	Steel beams with concrete deck. Original deck joints sliding plate and most still remain. APJ trials to reduce corrosion of steel beams due to water leakage. Techniflex PMB 600 APJ 220mm wide x 20mm depth installed in 1992 on small movement joint. Techniflex PMB 403 500mm wide x 20mm depth installed on main central movement joint in 1997. Joints only 20mm thick due to chipseal thickness and inability to cut into deck due to slenderness. Moderate traffic volumes.	Technics PMB600 APJ trial at small movement joint functioning well. No signs of deterioration at surface and assumed to be waterproof. Technics PMB 403 APJ at main joint has failed along joint line. Not waterproof. Joint movement assumed to be too great for installed joint thickness.

BRIDGE	LOCATION	YEAR OF CONSTRUCTION	DECK JOINT TYPES AND HISTORY	DECK JOINT PERFORMANCE
Ngaruroro Bridge	SH50A (new motorway)	1999	Five EMR joints 80mm movement gap with 40mm metal nosings. 180mm wide concrete nosings cast integral with deck, 25mm high. Two intermediate joints between EMR joints are poured sealant joints – movement is essentially only rotational at these joints. Moderate traffic volumes.	EMR joint gaps filled with chip but otherwise in good condition. Concrete nosing are proud of deck seal surface and ride quality is poor. Additional seal overlay planned to improve rideability.
Tutaekuri River Bridge	SH50 3/7.29	1968	Original joints compression seals with metal nosings. Poor performance especially leakage resulted in replacement with Techniflex PMB403 APJ's. Joints 290mm width x 30mm depth. Original steel angle nosings left in joints. Moderate traffic volumes.	Some joints appear in good condition after approximately 2 years service. Some signs of cracking at joint/chipseal interface but minor and of little concern. Several joints failing and breaking up due to loose original steel angle nosings. Bridging plate moving under traffic loads has caused entire sections of APJ to break out in wheel paths. Actual movement expected at joints is relatively low.
Westshore Bridge	SH2 638/0.00	1960	Original poured sealant joints leaking and replaced with Prismo APJ s in 1995. 600mm wide x 50-70 mm depth. Low movement joints. Moderate traffic volumes.	All joints in excellent condition. No signs of deterioration. Waterproof.
Waitangi Tutaekuri Bridge	SH2 650/8.34	1935	16 split pier joints originally poured sealant. Retrofitted with Prismo APJ's in 1994. 500mm wide x 30mm depth. Low movement joints. Moderate traffic volumes.	APJ s performing well. 1 or 2 joints showing shear failures in wheel paths. Waterproof.
Pakuratahi Stream Bridge	SH2 626/5.56	1965	3-4 poured sealant joints. One joint retrofitted in 1991 with Techniflex PMB600 trial to improve waterproofness. Joints chipsealed over. Moderate traffic volumes.	No cracking or other signs of deterioration in chipseal above APJ. Assumed to be waterproof. Significant crack reflecting through chipseal above all poured sealant joints.