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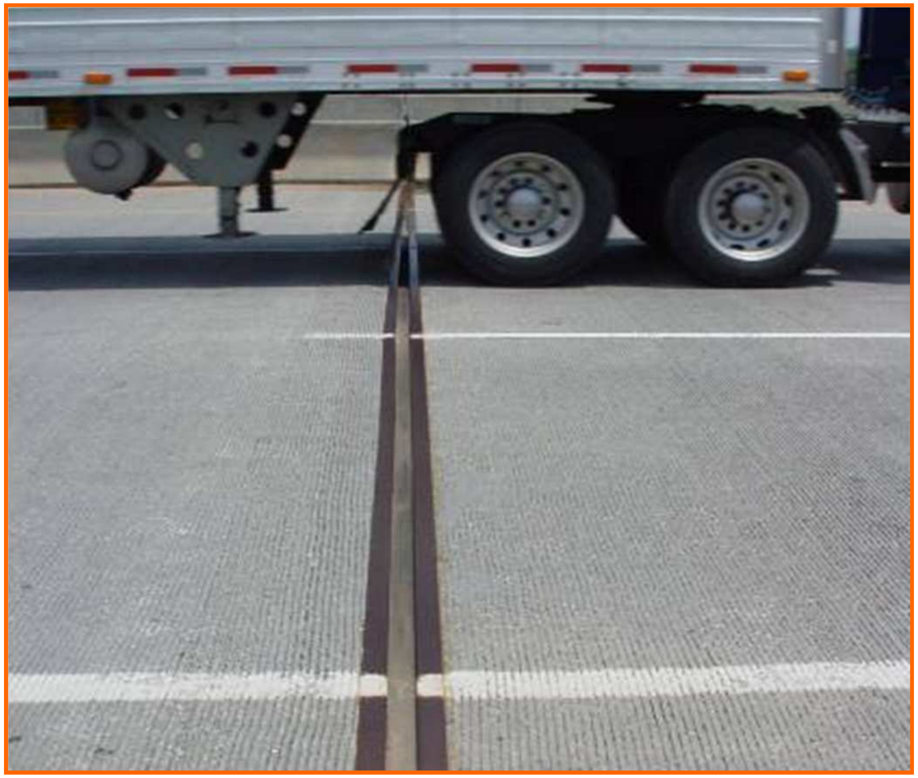
Concrete Bridge Deck Joints: State of the Practice

South-East Bridge Preservation Partnership
April 14, 2011
Raleigh, NC



Presented by
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Adapted from
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Brigham Young University

Introduction

- Cooling and heating of decks causes deck contraction and expansion, respectively
- When contraction is restrained, cracking can occur when the tensile stress exceeds the tensile strength
- When expansion is restrained, distortion or crushing can occur
- Joints are often specified to accommodate deck movements without compromising the structural integrity of the bridge

Introduction, Continued

- Bridge deck joints should protect the interior edges of concrete decks from vehicle loads, seal the joint openings, and accommodate movements resulting from temperature changes and creep and shrinkage of concrete
- Joint failure is a nationwide problem in the United States
- Failure is not necessarily caused by the joint material itself but also by careless design, improper installation, and inadequate maintenance

Problem: Incompressible Debris

Result: Failed Joint Seal

Consequences

- When joints fail, the integrity of the whole structure is affected!

Objectives

- Discuss the types of joints available for use on concrete bridge decks
- Review the performance characteristics of each type, including primary functions and movement ranges
- Discuss recent or current studies of joint performance

NCHRP Synthesis 319 (Purvis 2003)

- Performed a literature review
- Conducted a questionnaire survey – responders included 34 state DOTs and 10 Canadian Provinces about
  - Design procedures
  - Use and experiences
  - Construction practices
  - Maintenance and rehabilitation
  - Problems

Literature Review: Joint Types

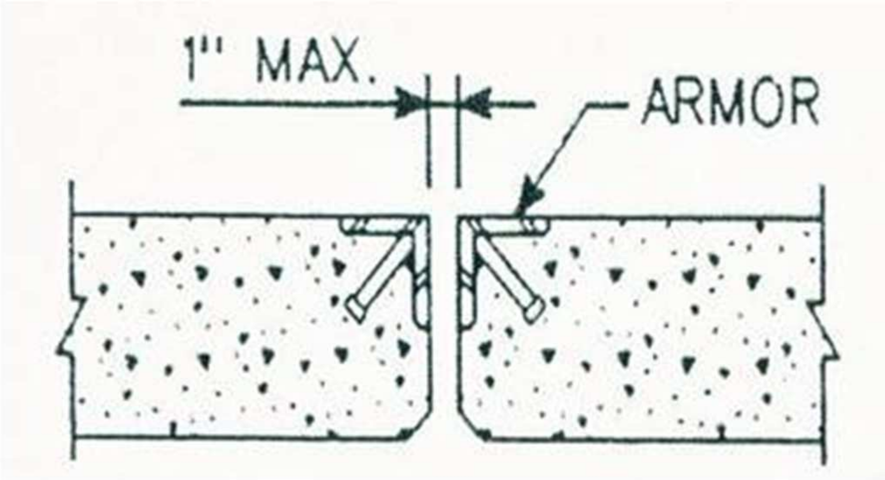
Open Joints

- Butt Joints
- Sliding Plate Joints
- Finger Joints

Closed Joints

- Poured Seals
- Asphalt Plug Joints
- Compression Seals
- Strip Seals
- Reinforced Elastomeric Joints
- Modular Elastomeric Joints

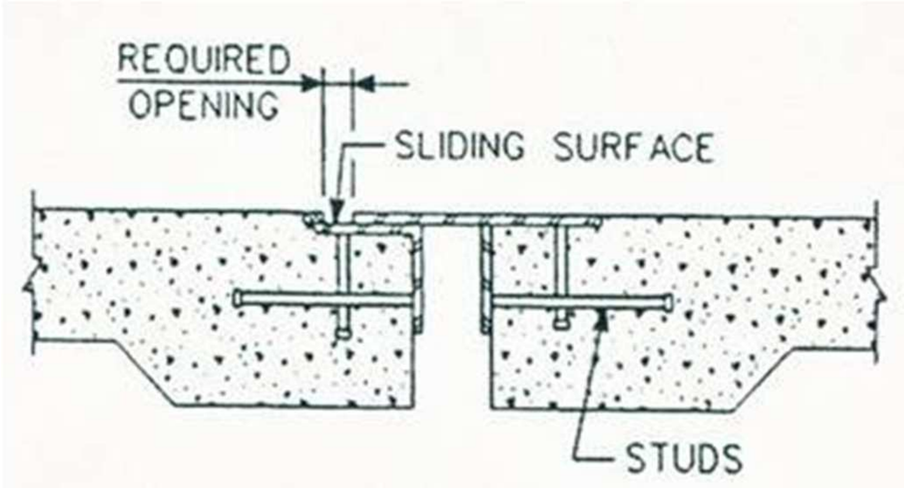
Butt Joints



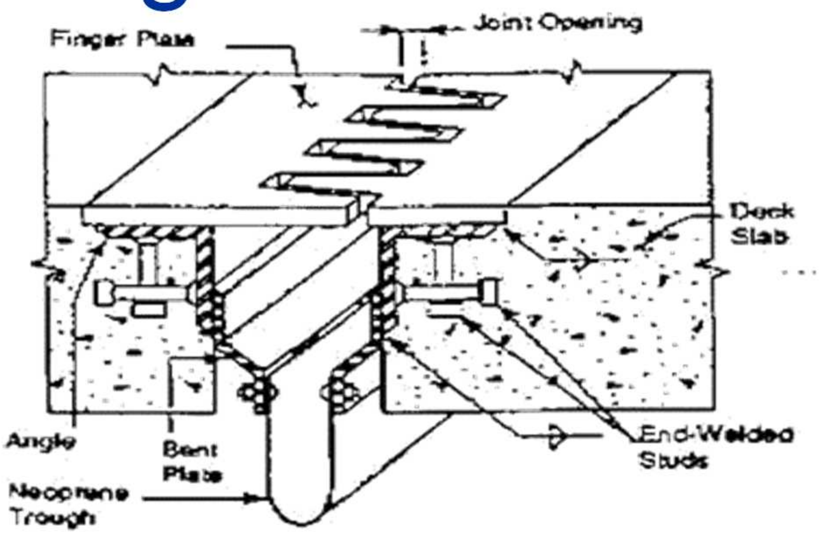
- Accommodate less than 1-in. movements or minor rotations
- Are sometimes installed with armor angles to protect concrete slabs
- Are effective only under the assumption that the passage of water and debris through the opening will not have adverse effects on the supporting substructures

Sliding Plate Joints

- Accommodate movements between 1 and 3 in.
- Are similar to a butt joint except that a plate is attached to one side, extending across the joint opening
- Partially stop debris from passing through openings
- May bend under repeated traffic loads and are susceptible to debris accumulation



Finger Joints



- Accommodate movements greater than 3 in.
- Are comprised of cantilevered fingers loosely interlocking each other over the opening
- Are sometimes installed with drainage troughs to catch and channel away water and debris
- Can jam, bend, or break during service due to horizontal and/or vertical misalignment during construction

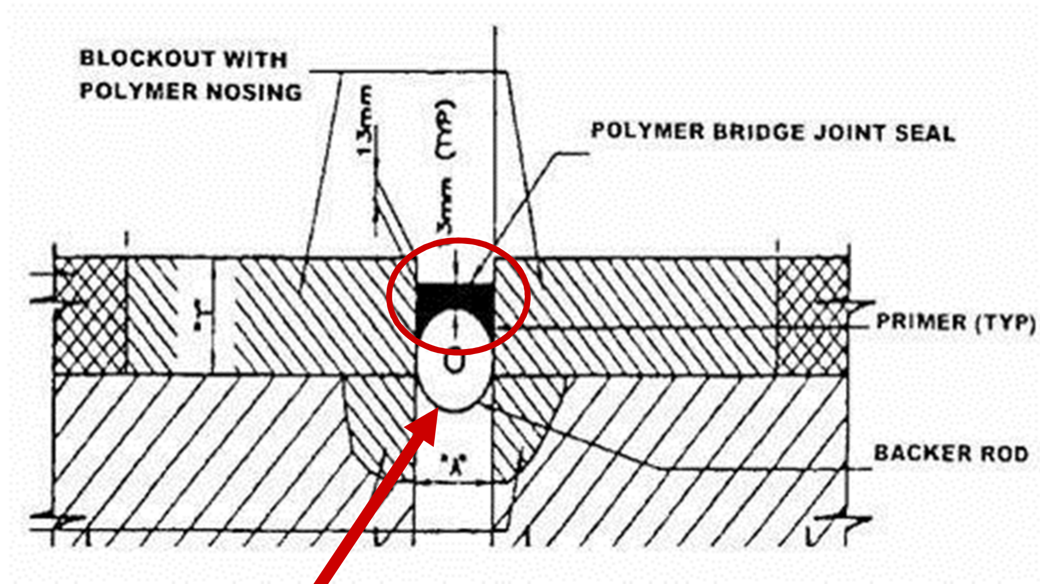
Open Joint w/ Trough

Troughs

- Troughs should be designed with adequate slope
- May require frequent flushing to prevent debris accumulation

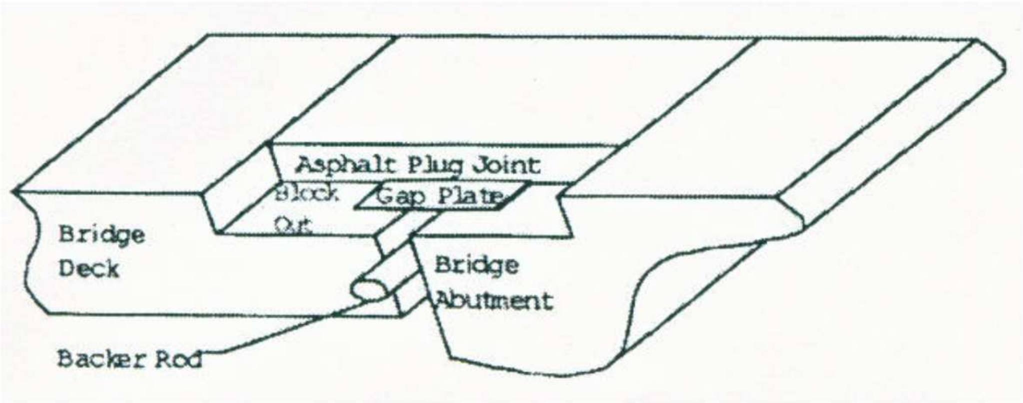
Poured Seals

- Accommodate movements up to 0.25 in.
- Generally consist of viscous, adhesive, and pourable waterproof silicone installed with backer rods to prevent the sealant from flowing down the joint
- Work best if sealant is poured when the ambient temperature is at the middle of the historical temperature range



Asphalt Plug Joints

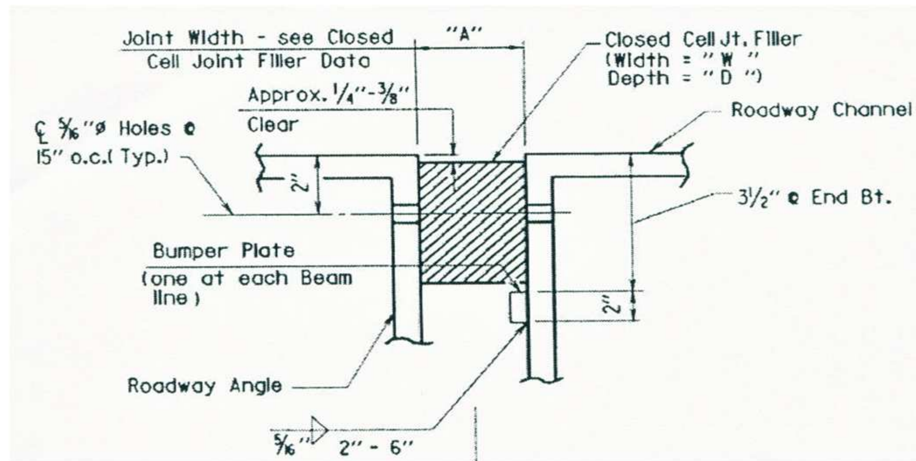
- Accommodate movements less than 2 in.
- Are constructed by placing a modified elasto-plastic bituminous binder with mineral aggregate in a block-out centered over the joint, with a backer rod in place
- Can sustain damage when subjected to very rapid changes in temperature

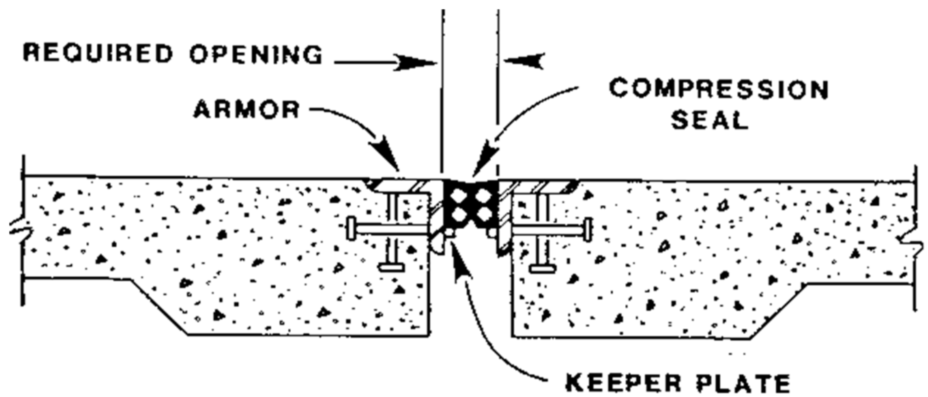


Asphalt Plug Joints

Compression Seals

- Accommodate movements less than 2½ in.
- Are typically classified as neoprene or cellular, both of which are installed using a lubricant that also serves as an adhesive agent
- Should be sized in a working range of 40 to 85% of the uncompressed width to ensure that positive contact pressure is always exerted against the face of the joint

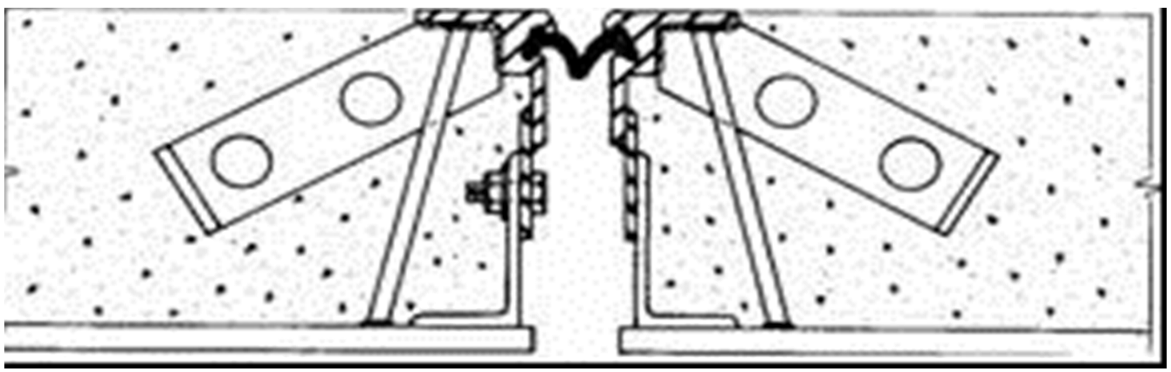




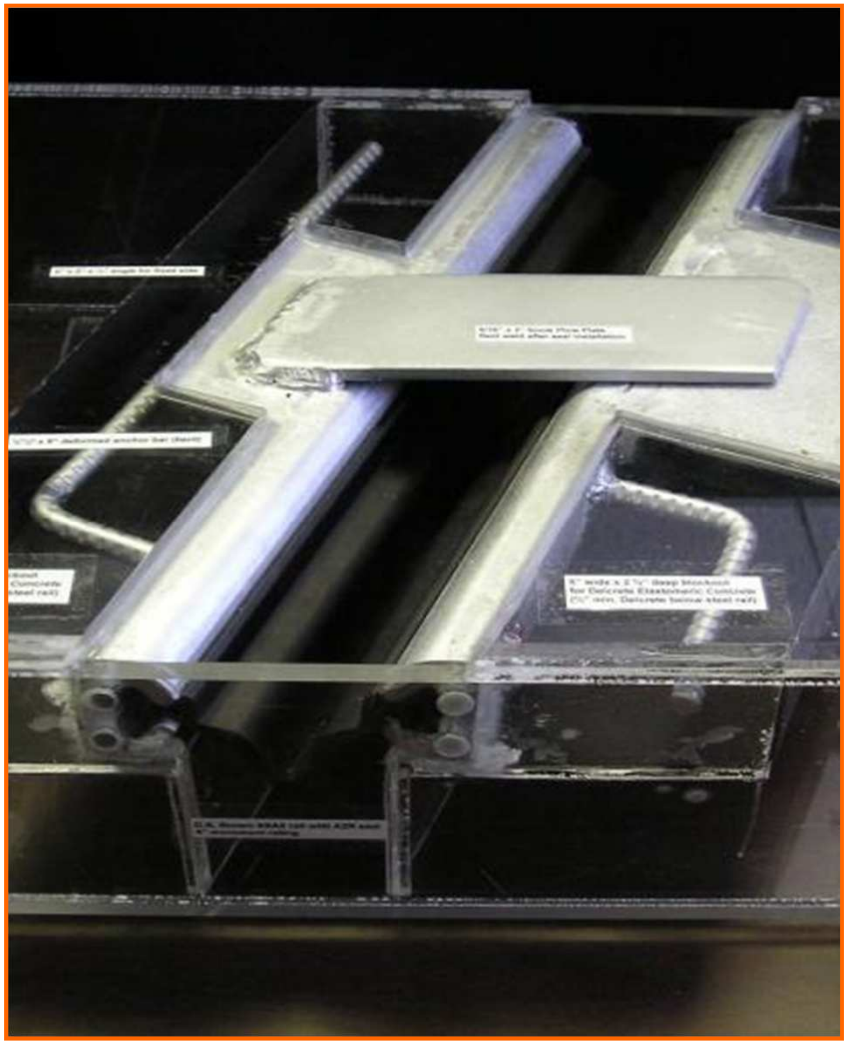
Compression Seals

Strip Seals

- Accommodate movements up to 4 in.
- Consist of a flexible neoprene membrane attached to two opposing side rails
- Can be susceptible to tearing, puncturing, or detachment under trafficking when debris accumulation rates are high
- Normally exhibit long service life, very good anchorage, and high degree of watertightness

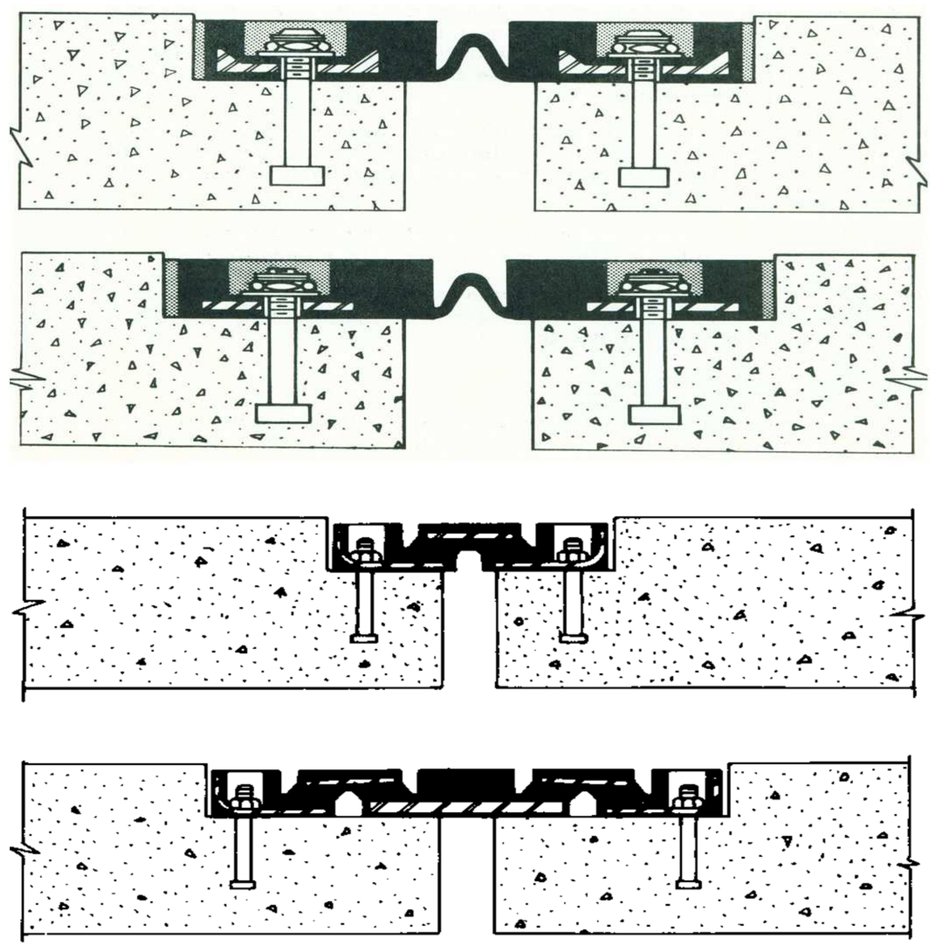


Strip Seals

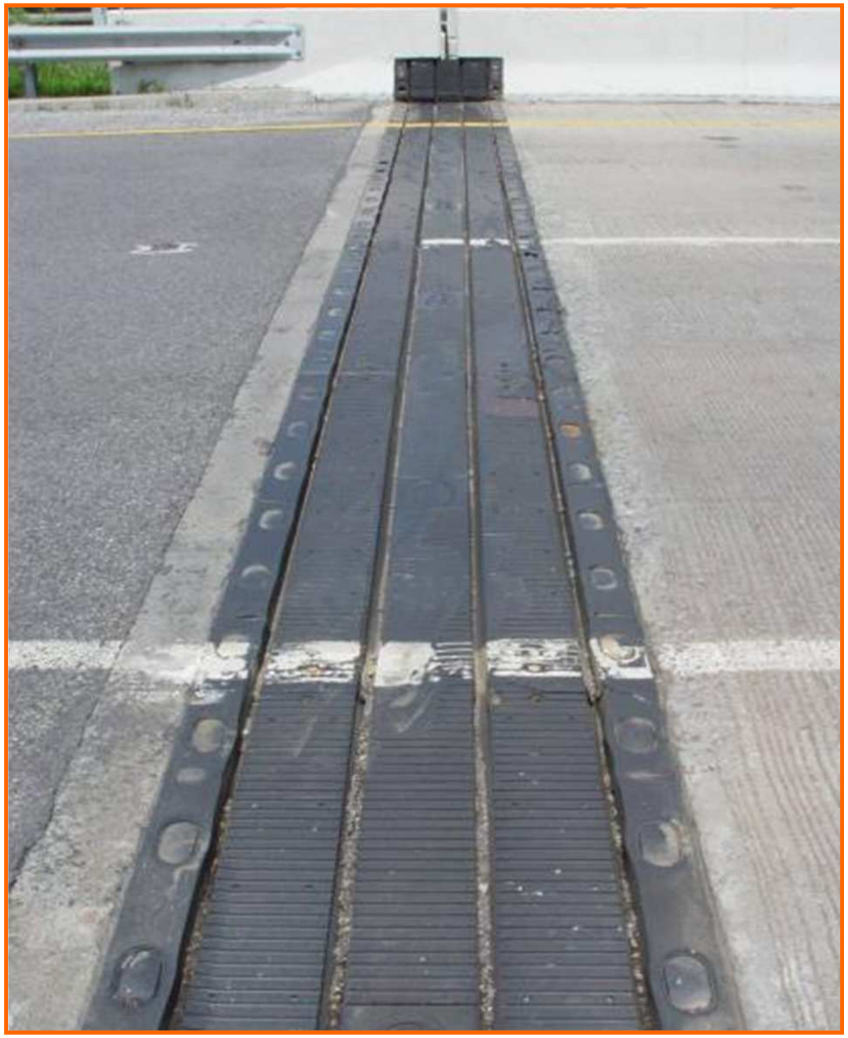


Reinforced Elastomeric Seals

- Accommodate movements between 2 and 6.5 in.
- Are classified as sheet seals or plank seals
- Are typically constructed using an epoxy bedding compound and cast-in-place studs
- Are susceptible to leakage at locations of field splices and at interfaces between the seal and the underlying concrete

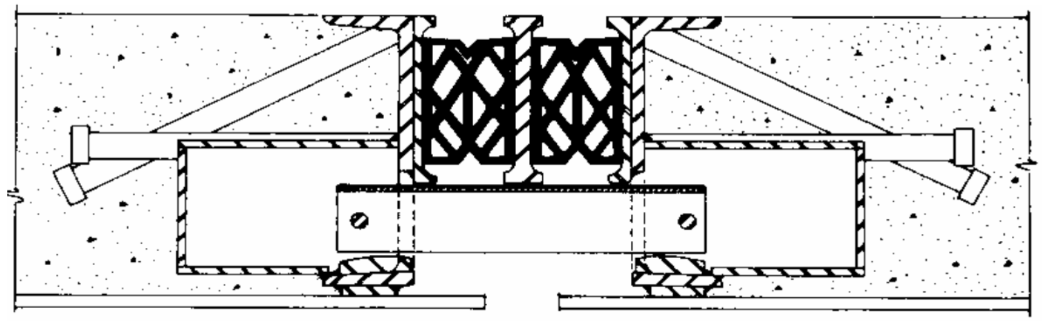


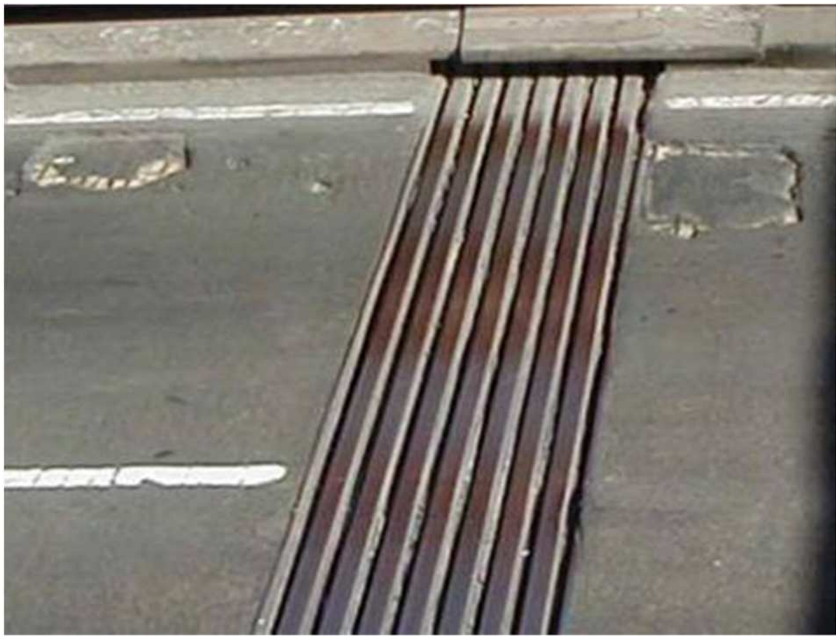
Reinforced Elastomeric Seals



Modular Elastomeric Joints

- Accommodate movements between 4 and 24 in. and up to 48 in. with special designs
- Consist of sealers, separator beams, and support bars
- Are susceptible to fatigue damage and leakage between compression seals and steel supports

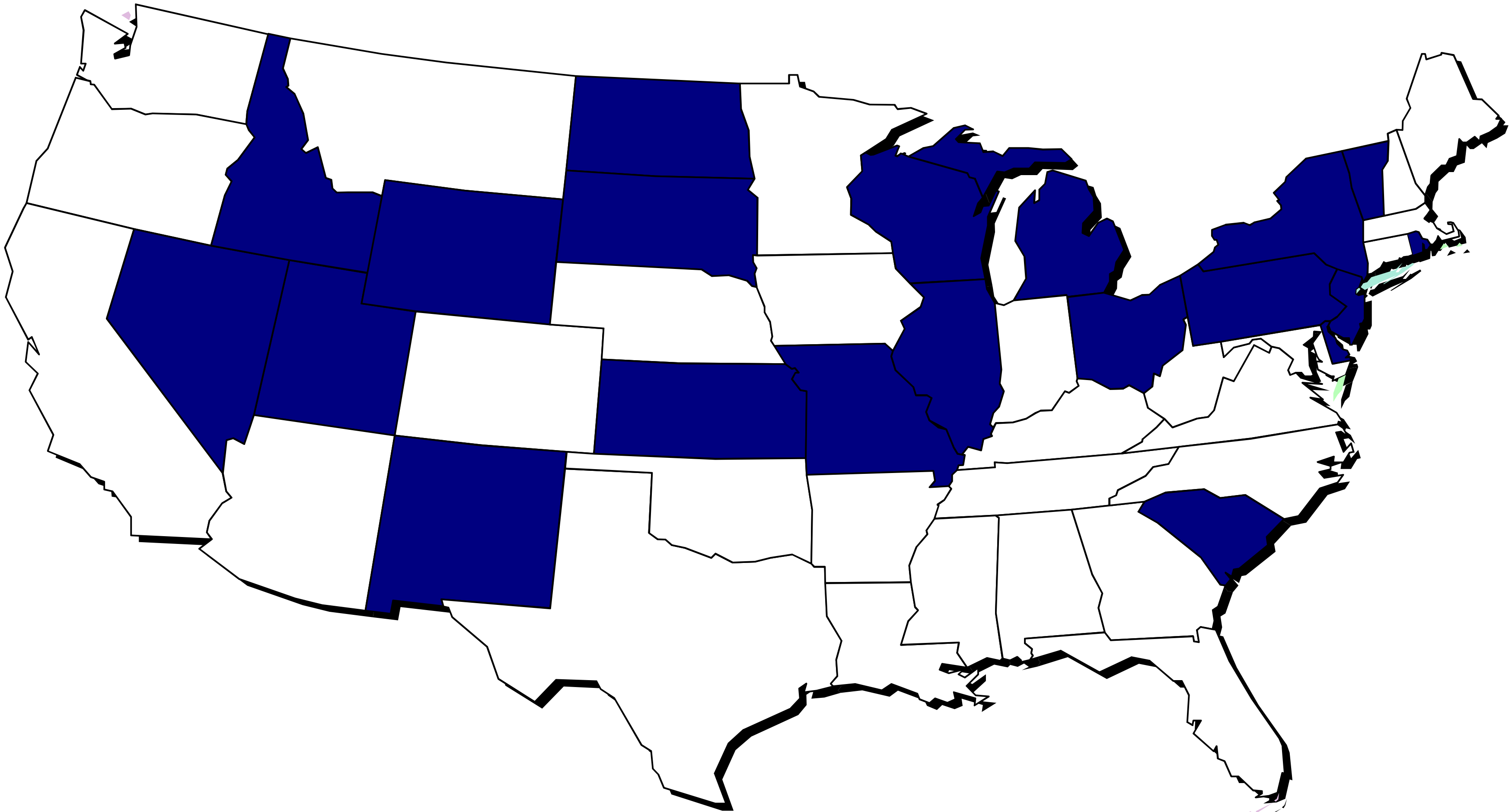




Utah Study (Guthrie 2005)

- Performed a literature review
- Conducted a questionnaire survey of state DOTs nationwide to determine the state of the practice for concrete bridge deck joint selection, maintenance, and replacement
  - Included 38 state DOTs in climates with freezing winter temperatures

Utah Study – Survey (Guthrie 2005)



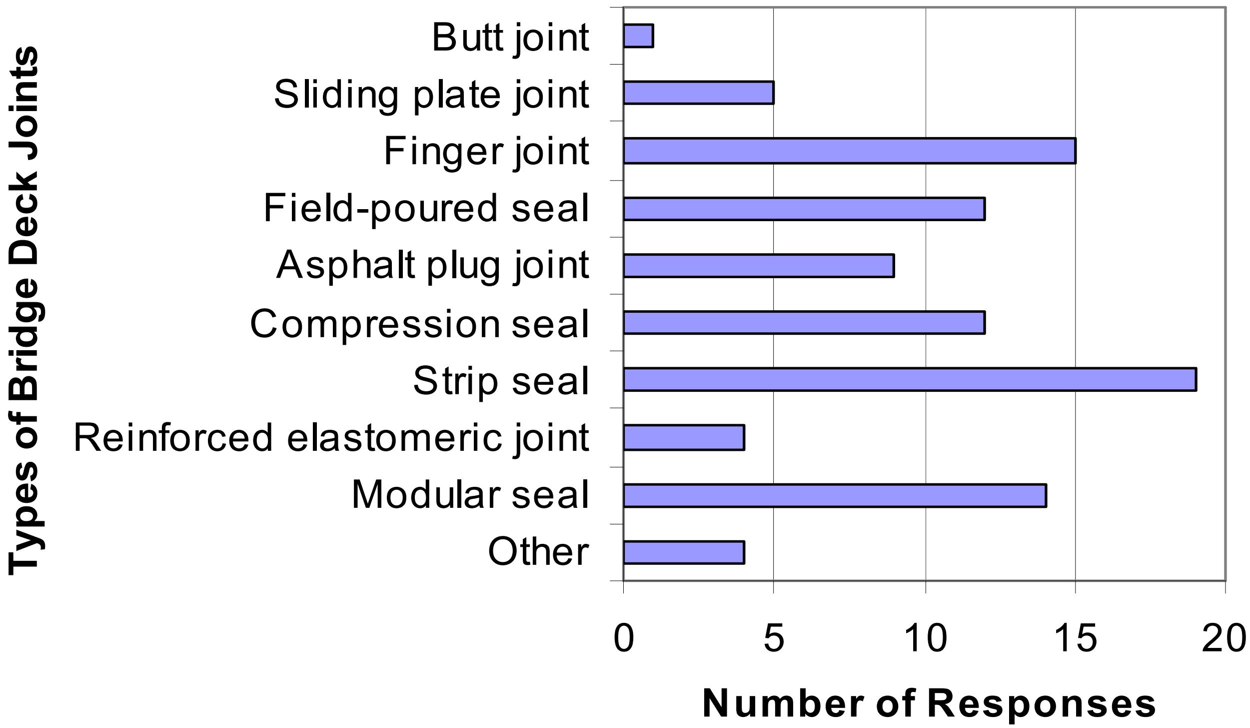
- Most of the 20 respondents were state bridge engineers or bridge maintenance specialists

Question 1: What is the typical range of movement you design concrete bridge deck joints to accommodate?

State	Expansion (in.)
Delaware	1
Idaho	2 to 5
Kansas	2 to 12
Michigan	2 to 4
Missouri	2
New Jersey	0 to 4
New Mexico	0.5 to 2.5
New York	1 to 2.5
Pennsylvania	2 to 12
South Dakota	0 to 4
Utah	1 to 6
Vermont	2
Wisconsin	0 to 12

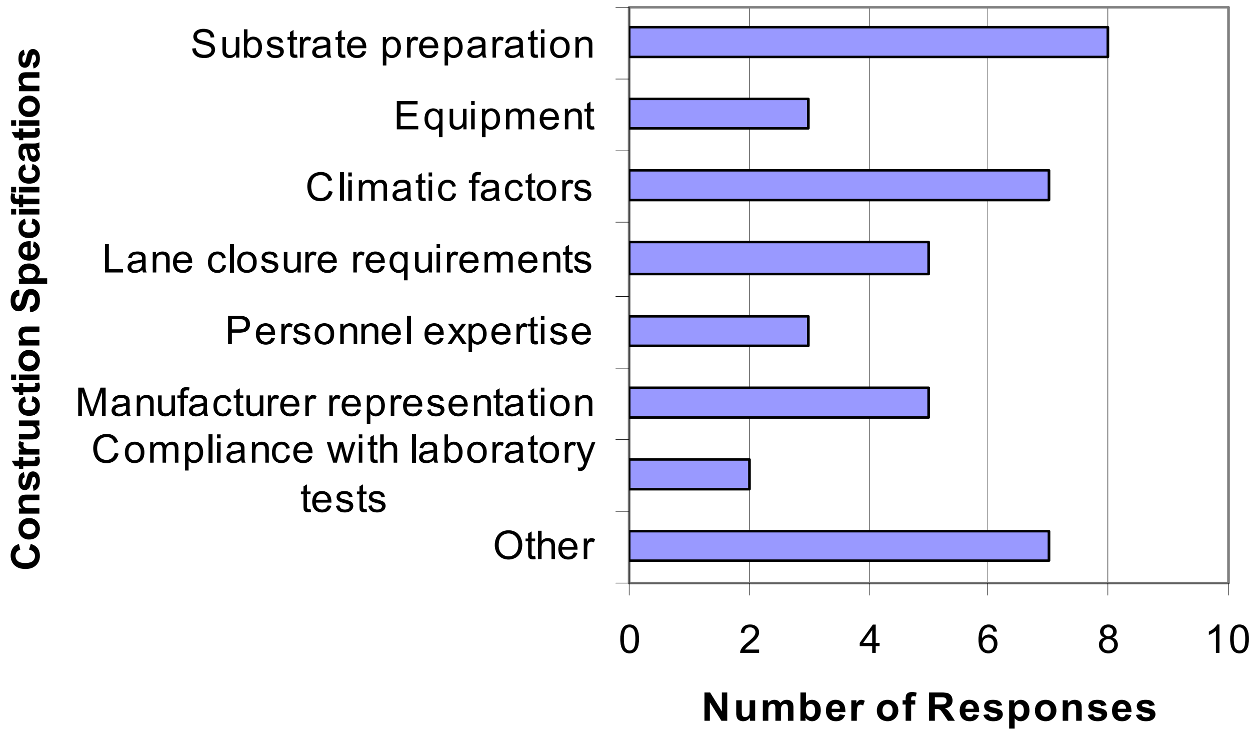
- Most common deck joint movements are in the range of 1 to 4 in.
- Two respondents specify jointless, integral abutment bridges

Question 2: What types of concrete bridge deck joints do you typically use?



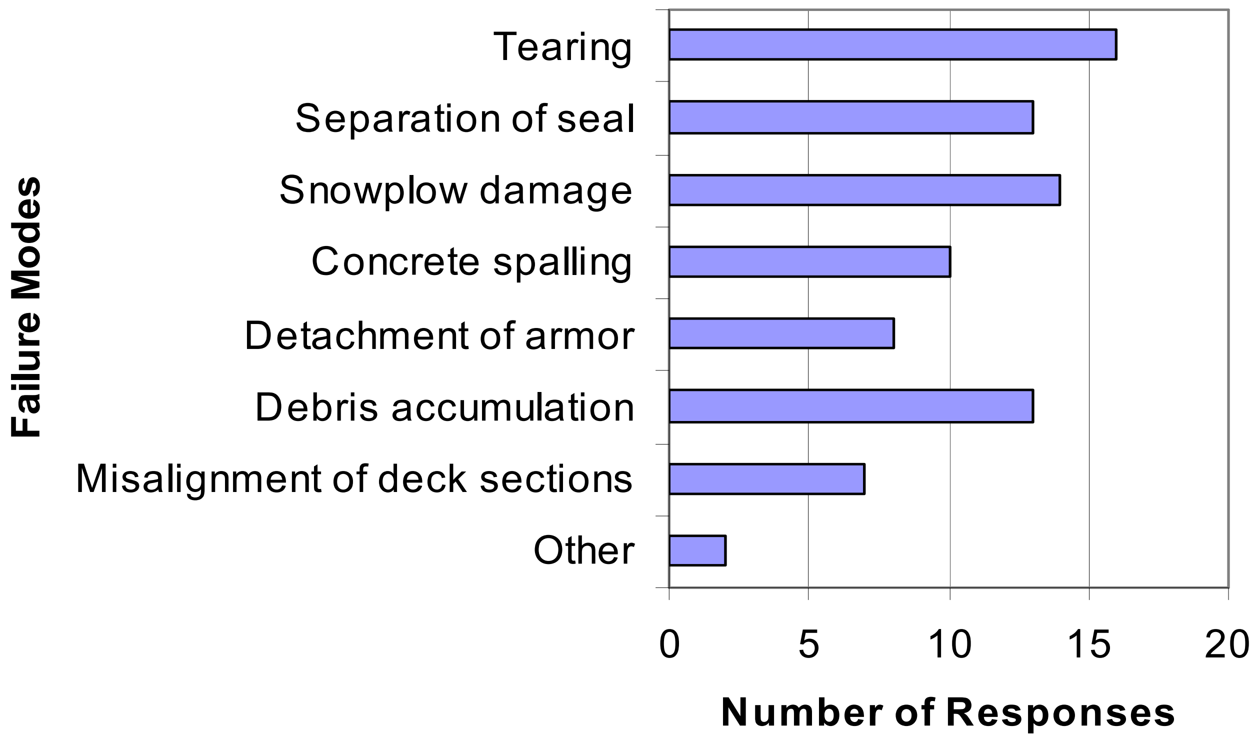
- Strip seals were most accepted type of joint, followed by finger joints

Question 3: What specifications do you use for construction of new decks or rehabilitation of aged decks to ensure good joint performance?



- Substrate preparation applied to repairs, climatic factors were usually minimum temperatures, and manufacturer representation generally involved 1 to 3 days of inspection

Question 4: What are the most common modes of failure for the deck joints you use?



- Although tearing and seal separation are applicable to only certain types of joints, snowplow damage and debris accumulation apply to all joint types

Question 5: Do you typically replace one type of concrete bridge deck joint with another type during rehabilitation?

- 11 of 20 respondents answered “yes” to this question
- The majority of the respondents replace compression seals and sliding plates with strip seals
- Some respondents choose to eliminate the use of joints if possible
- Some respondents replace armor-angle joint types with elastomeric concrete headers for use with poured or preformed joint materials

Question 6: Do you specifically avoid using certain types of concrete bridge deck joints?

- 11 of 20 respondents answered “yes” to this question
- Some respondents avoid the use of sliding plate, finger, asphalt plug, compression, and/or modular elastomeric joints for various reasons generally associated with past experience
- Some respondents do not permit the use of bolt-down joint armoring

Question 7: Do you conduct periodic inspection and maintenance of concrete bridge deck joints?

- 13 of 20 respondents answered “yes” to this question
- Most respondents follow the National Bridge Inventory reporting requirements concerning the type and frequency of data collection
- Some respondents schedule bridge cleaning, including joints, in conjunction with bridge inspections

Design Recommendations (Guthrie 2005)

- Design decks with as few joints as possible
- Design joints for movements that are likely to occur
- Consider future inspection, maintenance, and replacement during design
- Subject proposed joints to load tests
- Set drains uphill of joints to minimize water ingress
- Coat steel devices with paint or galvanization
- Specify materials appropriate for the local climate
- Design armor anchors (if used) to resist pull-out and snow plow impacts
- Consider using elastomeric concrete or other shock-absorbing embedment materials around anchorages

Installation Recommendations (Guthrie 2005)

- Give the contractor adequate time to complete joint installations without rushing
- Enforce inspection at all times
- Place joints and armor between 1/8 and 5/32 in. below the deck surface to minimize snow plow damage
- Ensure expulsion of entrapped air from beneath joint-edge armor during concrete placement
- Use continuous seals
- Place troughs with a slope of at least 8 percent to prevent debris accumulation
- Place backer rods at appropriate depth to achieve desirable shape factor

Maintenance Recommendations (Guthrie 2005)

- Replace the entirety of failed joints to avoid field splices
- Repair damaged areas in approach slabs to reduce impact loads on joints
- Clean drains, joints, and troughs at least once a year
- Repaint steel devices periodically to prevent rusting

Other Recent Studies

- “Performance of Strip Seals in Iowa Bridges: Pilot Study” – Bolluyt 2001 for Iowa DOT
- “Evaluation of Asphaltic Expansion Joints” – Mogawer 2004 for New England Transportation Consortium
- “Sealing Of Small Movement Bridge Expansion Joints” – Malla et al 2006 for New England Transportation Consortium
- “Evaluation of modular expansion dams” – Sukley 2008 Project #RP97-052 for PennDOT.

Other Recent Studies

- "Material Property and Quality Control Specifications for Elastomeric Concrete Used at Bridge Deck Joints" – Gergely 2009 UNC-Charlotte for NCDOT.
- "Evaluation of Asphalt Bridge Deck Joint Systems" – Ghafoori 2009 for Nevada DOT

NETC survey (Malla 2006)

State	Types of Joints Employed	Anticipated Movement Range (MR) or Deck Span Length (L)	Comments
Connecticut	a. **Asphaltic Plug Joint** b. Silicone Sealant c. Neoprene Strip Seal d. Modular and Finger Plate	MR < 40 mm MR: 40-80 mm MR: 80-100 mm MR > 100 mm	**95 % of all joints** Elastomeric header Elastomeric header -
Maine	a. **Compression Seal** b. Silicone -Pour-in-Place c. Gland Seal d. Evazote Seal e. Asphaltic Plug Joint	- Small MR MR > 100mm - MR < 50mm	**Most preferred** Rehabilitation project - Limited success No success, Failure in short period
Massachusetts	a. Saw Cut Seal b. Asphaltic Plug Joint c. Strip Seal d. Finger Joint	L < 15 m L > 20m, <35m L > 35 m Large spans	- Skew < 25º Armored Neoprene trough

NETC survey (Malla 2006)

State	**Types of Joints Employed**	**Anticipated Movement Range (MR) or Deck Span Length (L)**	**Comments**
New Hampshire	a. Silicone based Sealant b. Roadway Crack Sealer c. **Asphaltic Plug Joint** d. Finger Joint	Small MR For short spans and on fixed ends L: 80’-140’ L: 140’-180’	Reasonable success Hot applied, petroleum based **Good results**, skew <25º -
Rhode Island	a. Compression Seal b. Strip Seal c. **Asphaltic Plug Joint** d. Open Joints, Sliding Plate Joint	- Large MR Short Spans (L<100’) -	Poor performance, No more in use Poor performance, Leakage **Most preferred** Exist in old construction
Vermont	a. **Asphaltic Plug Joint** b. Vermont Joint c. Finger Plate Joint d. Modular Joints	MR: 50-75mm;Short Spans (L<90’) MR < 75mm (L>90’) MR > 75mm Very Large MR.	**Most preferred** - - Rarely used

Other Ongoing Research

- “Simplifying bridge expansion joint design and maintenance” SC project # 677, at the University of South Carolina.
- “Evaluation of Silicone Joint Sealers” Arkansas TRC Project 0703
- “Investigative Study of In-state Use of Asphaltic Plug Expansion Joints” UNLV for Nevada DOT

Other Ongoing Research

- SCOM Survey (Palle, 2010)
- Kentucky Transportation Center and AASHTO SCOM (Subcommittee on Maintenance)
- Part of research to identify and employ the most effective bridge joints for specific applications
- Two surveys - responses from 32 states :
  - Engineers in design and construction (28 responses)
  - Engineers in maintenance (27 responses)

SCOM Survey

Survey of Materials and Practices Related to Bridge Expansion Joint Maintenance

This survey is a national survey of joints submitted by the AASHTO Subcommittee on Maintenance Bridge Technical Working Group. Please contact Sudhir Palle at 859-257-2670 or Sudhir@engr.uky.edu, if you have any questions regarding the survey. Please send the completed surveys to the same email address. We will email all responders a summary of the survey results.

The responder should feel comfortable in generalizing and approximating where specific detailed information is not readily available.

Responder Information

Date

Agency: Virginia DOT

Responder

Title

Phone

e-mail

Inspection Criteria

1. Do you use element level bridge inspections? Yes ☑ No ☐
2. In rating joint condition, do you include:
   - Seal physical condition (torn, crushed): Yes ☑ No ☐
   - Steel hardware condition (beams, plates, fingers): Yes ☑ No ☐
   - Adjacent pavement/deck condition (spalling, armored edges, rutting): Yes ☑ No
   - Water tightness of the joint: Yes ☑ No ☐
   - Debris accumulation of joint seals: Yes ☑ No ☐
   - Debris accumulation in trough, if present: Yes ☑ No ☐

Maintenance Practices

3. What actions do you employ for maintenance of joints?
   - Seal repairs/replacement: Yes ☑ No ☐

- Expect results to be summarized and reported at AASHTO meeting in June

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	A	B	C	D	E	F	G
1		State	Illinois	New York	North Carolina	New Jersey	Colorado
2		Responder and Title	Carl Puzey Engineer of Structural Services	Douglas Rose Regional Bridge Maintenance Engineer	Daniel D. Holderman State Br Mgt Engr	Christian Espitia Assistant Engineer	Tom Tatalaski II EIT III
3		Agency	Illinios D.O.T.	New York D.O.T.	North Carolina D.O.T.	New Jersey D.O.T.	Colorado D.O.T.
4	1	Element level bridge inspections	yes	yes	no	yes	yes
5	2	In rating joint condition do you include					
6	a.	seal condition	yes	yes	yes	yes	yes
7	b.	steel hardware condition	yes	yes	yes	yes	yes
8	c.	pavement deck condition	yes	no	yes	yes	yes
9	d.	water tightness of the joint	yes		yes	yes	yes
10	e.	debris accumulation on joint seals	no	[illegible]	yes	yes	no
11	f.	debris accumulation in trough	no	no	yes	yes	no
12	3	What actions do you employ for maintenance of joints					
13	a.	seal repairrs/replacement	yes	yes	yes	yes	yes
14		If yes, what existing seal condition criteria are used in making that decision	judgement of district bridge maintenance based on torn or cracked or leaking seals	if its out of the deck and laying on the joint, its not performing as designed, likewise if its laying under the bridge or completely seperated from one or both of the headers	Usually when seal is missing or damaged	Missing filling material at the joints. Expansion paper joints from previous joint header repairs.	Recommend repair or replacement to seal, if the seals are torn, shredded, or allowing water and debris through the joint. If the seal is missing, pulled out, or the anchoring device is failing we recommend repair or replacement of the joint
15	b.	Joint hardware repairs	yes	yes	yes	no	yes
16		If yes, what existing joint hardware criteria are used in making that decision	repair of existing steel armor is rare if repair is needed concrete removal around the joint is typical with complete replacement of the expansion joint	joint banging and/or bouncing with the traffic	Usually when missing or damaged. If movement is in range of using evazote, aluminum and steel modular joints are replaced with elastomeric concrete and evazote		Recommend repair or replacement of the joint, if the hardware is failing, such as the anchoring hardware is failing or components of the hardware are broken or failed. A cracked weld to joint hardware or loose anchoring hardware are other criteria that we recommend for repair or replacement
17	c.	Adjacent deck (D-cracking) repairs	no	yes	no	yes	yes
		If yes, what existing criteria are used in making that decision	n/a	headers spalled and potholed	n/a	Broken or unsound concrete joint headers.	Recommend repair or sealing area around the joint, if the adjacent deck cracking is causing active leaking around the joint. Also, sealing or repairing the area of the joint, if the end dams are moderately cracking with impending potholes.

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Thank you

Questions?