

Rapid Replacement of Bridge Deck Expansion Joints Study – Phase I



**Interim Report
December 2014**



IOWA STATE UNIVERSITY
Institute for Transportation

Sponsored by
Iowa Department of Transportation
Federal Highway Administration
(InTrans Project 13-451)

About InTrans

The mission of the Institute for Transportation (InTrans) at Iowa State University is to develop and implement innovative methods, materials, and technologies for improving transportation efficiency, safety, reliability, and sustainability while improving the learning environment of students, faculty, and staff in transportation-related fields.

About CMAT

The mission of the Construction Management and Technology (CMAT) Program is to improve the efficiency and cost-effectiveness of planning, designing, constructing, and operating transportation facilities through innovative construction processes and technologies.

Disclaimer Notice

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the sponsors.

The sponsors assume no liability for the contents or use of the information contained in this document. This report does not constitute a standard, specification, or regulation.

The sponsors do not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document.

ISU Non-Discrimination Statement

Iowa State University does not discriminate on the basis of race, color, age, ethnicity, religion, national origin, pregnancy, sexual orientation, gender identity, genetic information, sex, marital status, disability, or status as a U.S. veteran. Inquiries regarding non-discrimination policies may be directed to Office of Equal Opportunity, Title IX/ADA Coordinator, and Affirmative Action Officer, 3350 Beardshear Hall, Ames, Iowa 50011, 515-294-7612, email eooffice@iastate.edu.

Iowa DOT Statements

Federal and state laws prohibit employment and/or public accommodation discrimination on the basis of age, color, creed, disability, gender identity, national origin, pregnancy, race, religion, sex, sexual orientation or veteran's status. If you believe you have been discriminated against, please contact the Iowa Civil Rights Commission at 800-457-4416 or the Iowa Department of Transportation affirmative action officer. If you need accommodations because of a disability to access the Iowa Department of Transportation's services, contact the agency's affirmative action officer at 800-262-0003.

The preparation of this report was financed in part through funds provided by the Iowa Department of Transportation through its "Second Revised Agreement for the Management of Research Conducted by Iowa State University for the Iowa Department of Transportation" and its amendments.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Iowa Department of Transportation or the U.S. Department of Transportation.

Technical Report Documentation Page

1. Report No. InTrans Project 13-451		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Rapid Replacement of Bridge Deck Expansion Joints Study – Phase I				5. Report Date December 2014	
				6. Performing Organization Code InTrans Project 13-451	
7. Author(s) Adam M. Miller and Charles T. Jahren				8. Performing Organization Report No.	
9. Performing Organization Name and Address Institute for Transportation Iowa State University 2711 South Loop Drive, Suite 4700 Ames, IA 50010-8664				10. Work Unit No. (TR AIS)	
				11. Contract or Grant No.	
12. Sponsoring Organization Name and Address Iowa Department of Transportation 800 Lincoln Way Ames, IA 50010				13. Type of Report and Period Covered Phase I Interim Report	
				14. Sponsoring Agency Code SPR RB33-013	
15. Supplementary Notes Visit www.intrans.iastate.edu for color pdfs of this and other research reports.					
16. Abstract <p>Bridge deck expansion joints are used to allow for movement of the bridge deck due to thermal expansion, dynamics loading, and other factors. More recently, expansion joints have also been utilized to prevent the passage of winter de-icing chemicals and other corrosives applied to bridge decks from penetrating and damaging substructure components of the bridge. Expansion joints are often one of the first components of a bridge deck to fail and repairing or replacing expansion joints are essential to extending the life of any bridge.</p> <p>In the Phase I study, the research team focused on the current means and methods of repairing and replacing bridge deck expansion joints. Research team members visited with Iowa Department of Transportation (DOT) Bridge Crew Leaders to document methods of maintaining and repairing bridge deck expansion joints. Active joint replacement projects around Iowa were observed to document the means of replacing expansion joints that were beyond repair, as well as, to identify bottlenecks in the construction process that could be modified to decrease the length of expansion joint replacement projects.</p> <p>After maintenance and replacement strategies had been identified, a workshop was held at the Iowa State Institute for Transportation to develop ideas to better maintain and replace expansion joints. Maintenance strategies were included in the discussion as a way to extend the useful life of a joint, thus decreasing the number of joints replaced in a year and reducing the traffic disruptions.</p>					
17. Key Words bridge deck—bridge joint repair—bridge maintenance—expansion joint replacement				18. Distribution Statement No restrictions.	
19. Security Classification (of this report) Unclassified.		20. Security Classification (of this page) Unclassified.		21. No. of Pages 71	22. Price NA

RAPID REPLACEMENT OF BRIDGE DECK EXPANSION JOINTS STUDY – PHASE I

**Interim Report
December 2014**

Principal Investigator
Charles T. Jahren, Professor
Construction Management and Technology
Institute for Transportation, Iowa State University

Research Assistant
Adam M. Miller

Authors
Adam M. Miller and Charles T. Jahren

Sponsored by
the Iowa Department of Transportation and
the Federal Highway Administration
(InTrans Project 13-451)

Preparation of this report was financed in part
through funds provided by the Iowa Department of Transportation
through its Research Management Agreement with the
Institute for Transportation

A report from
Institute for Transportation
Iowa State University
2711 South Loop Drive, Suite 4700
Ames, IA 50010-8664
Phone: 515-294-8103
Fax: 515-294-0467
www.intrans.iastate.edu

TABLE OF CONTENTS

ACKNOWLEDGMENTS	vii
EXECUTIVE SUMMARY	ix
CHAPTER 1. INTRODUCTION	1
1.1 Objectives	1
1.2 Report Organization.....	1
CHAPTER 2. DETERIORATION PATTERNS AND MAINTENANCE EFFORTS.....	2
2.1 Chapter Overview	2
2.2 Introduction.....	2
2.3 Research Methodology	2
2.4 Sliding Plate Expansion Joints.....	2
2.5 Strip Seal and Compression Seal Joints.....	8
2.6 Finger Joints and Modular Expansion Joints.....	16
2.7 Integral Abutment Joints.....	21
CHAPTER 3. CURRENT JOINT REPLACEMENT PRACTICES.....	23
3.1 Chapter Overview	23
3.2 Introduction.....	23
3.3 Northbound I-380 Joint A Replacement.....	23
3.4 US 18 over the Wapsipinicon River	34
CHAPTER 4. RAPID RELACEMENT OF EXPANSION JOINT WORKSHOP	39
4.1 Introduction.....	39
4.2 Summary of Previous Research Tasks.....	39
4.3 Pertinent Iowa DOT Design Standards and Design Considerations.....	42
4.4 Breakout Groups, Idea Discussion, and Ranking	43
4.5 Workshop Results	44
CHAPTER 5. CONCLUSION AND CONTINUING RESEARCH EFFORTS.....	47
5.1 Conclusion	47
5.2 Continuing Research Efforts.....	47
REFERENCES	49
APPENDIX A. WORKSHOP PARTICIPANTS, OVERVIEW, AND RESULTS.....	51
APPENDIX B. WORKSHOP GROUP DISCUSSION NOTES.....	55

LIST OF FIGURES

Figure 2.1. Large sections of a plate broken loose on northbound I-380 Exit 19A in Cedar Rapids, Iowa	4
Figure 2.2. Gap forming between top of abutment and approach panel on the I-80 over I-35 west abutment.....	5
Figure 2.3. Rusted top plate beneath a raise plate showing relatively good condition on westbound US 20 over Catfish Creek in Cedar Rapids, Iowa	6
Figure 2.4. Extreme case of sliding plate joint maintenance	7
Figure 2.5. Strip seal joint.....	8
Figure 2.6. Compression seal joint	9
Figure 2.7. Badly weathered, but still functioning, strip seal joint.....	10
Figure 2.8. Strip seal joint with missing extrusion section	14
Figure 2.9. Compression seal joint with failed section of armoring.....	15
Figure 2.10. Silicoflex expansion joint example	16
Figure 2.11. Modular expansion joint.....	17
Figure 2.12. Neoprene trough below finger expansion joint	18
Figure 2.13. Exposed piling from slope erosion	19
Figure 2.14. Debris collection in modular expansion joint preventing full closure of the joint	19
Figure 2.15. New Iowa DOT standard detail for wing wall armoring.....	22
Figure 3.1. Northbound I-380 project location	24
Figure 3.2. Approximate locations of expansion joints	25
Figure 3.3 Typical I-380 concrete removal cross section	26
Figure 3.4 Aqua Cutter hydrodemolition machine	29
Figure 3.5. Joint A after hydrodemolition	30
Figure 3.6 Concrete remaining after hydrodemolition	31
Figure 3.7. Flexible shaft vibratory compactor.....	33
Figure 3.8. US 18 Over Wapsipinicon River project location.....	34
Figure 3.9. Typical US 18 removal cross section	35
Figure 3.10. Replacement paving notch plan.....	36
Figure 3.11. US 18 possible detour route	38

LIST OF TABLES

Table 3.1. Construction task length by hour	28
Table 3.2. Total construction task lengths	29

ACKNOWLEDGMENTS

The authors would like to thank the Iowa Department of Transportation (DOT) for sponsoring this research as well as the Federal Highway Administration for state planning and research (SPR) funds used for this project.

The authors would like to thank the technical advisory committee for this project including Dean Bierwagen, Mark Carter, Dan Cramer, Matt Johnson, Linda Narigon, James Nelson, Steve Sandquist, Justin Sencer, and Wayne Sunday. A multitude of Iowa DOT, personnel too numerous to list, were engaged on this project and the authors would like to thank each of them for their individual contributions.

Finally, the authors would like to thank Roger Anderson, Steve Kunz, Stan Stallsmith, and Andy Stone for their contributions to our research.

EXECUTIVE SUMMARY

Bridge deck expansion joints are used to allow for movement of the bridge deck due to thermal expansion, dynamics loading, and other factors. More recently, expansion joints have also been utilized to prevent the passage of winter de-icing chemicals and other corrosives applied to bridge decks from penetrating and damaging substructure components of the bridge. Expansion joints are often one of the first components of a bridge deck to fail and repairing or replacing expansion joints are essential to extending the life of any bridge.

In this Phase I study, the research team focused on documenting the current means and methods of bridge expansion joint deterioration, maintenance, and replacement and on identifying improvements through all of the input gathered.

Research team members visited with Iowa Department of Transportation (DOT) Bridge Crew Leaders to document methods of maintaining and repairing bridge deck expansion joints. Active joint replacement projects around Iowa were observed to document the means of replacing expansion joints that were beyond repair, as well as, to identify bottlenecks in the construction process that could be modified to decrease the length of expansion joint replacement projects.

After maintenance and replacement strategies had been identified, a workshop was held at the Iowa State Institute for Transportation to develop ideas to better maintain and replace expansion joints. Maintenance strategies were included in the discussion as a way to extend the useful life of a joint, thus decreasing the number of joints replaced in a year and reducing the traffic disruptions.

The results of this phase of the research provide details about the types of failure experienced with expansion joints in Iowa, measures taken to repair and prevent these types of failures, current construction methods undertaken by contractors in Iowa, and hypothesized ways to improve methods of expansion joint repair and maintenance.

Since a significant portion of this research phase focused on the current state of expansion joints and on developing novel ideas to rapidly repair expansion joints, some results may be contracted as future projects for more detailed evaluation.

CHAPTER 1. INTRODUCTION

Bridge deck expansion joints are the components of a bridge that allow for movement of the bridge deck due to thermal expansion, dynamic loading, and several other factors. More recently, expansion joints have had a secondary function of preventing the passage of water. This water often contains deicing salts and other corrosive chemicals that are harmful to the substructure of the bridge.

Expansion joints are often one of the first components of a bridge to fail. Failure can be due to increased traffic loading, component fatigue, low quality work, or several other factors. Joint failure can lead to increased damage to bridge substructures including rust formation on metal bearings as well as increased spalling on precast beam ends, concrete abutments, and concrete piers. To prevent further bridge damage, joints are often repaired or replaced.

Joint replacements are particularly problematic construction projects, often requiring traffic closures to allow work completion. Traffic closures are undesirable and often require staged jobs and difficult working conditions. Completing work during low traffic periods, nights, and weekends can help alleviate traffic concerns. However, it is challenging to complete a repair in a very short period of time or at night while still maintaining the necessary joint quality. Improved methods to rapidly repair and replace bridge deck expansion joints are desirable.

1.1 Objectives

The objectives of this research are two-fold, to both examine both current means and methods as well as develop new methods of replacing expansion joints. This research provides the Iowa Department of Transportation (DOT) with detailed information about the types of failure experienced by expansion joints, measures taken by the Iowa DOT to repair and prevent these types of failures, current construction methods undertaken by contractors in Iowa, and hypothesized ways to improve methods of expansion joint repair and maintenance.

A significant portion of this research is focused on the current state of expansion joints and developing novel ideas to rapidly repair expansion joints, so some results may be contracted as future projects for more detailed evaluation.

1.2 Report Organization

This report is organized into several chapters. Chapter 1 contains a brief introduction. Chapter 2 contains field gathered information on the rate and types of expansion joint deterioration in Iowa as well as the methods undertaken by the Iowa DOT to repair these joints. Chapter 3 contains detailed observations of current construction methods practiced by contractors on several different expansion joint replacement projects in Iowa. Chapter 4 contains the summary and results of a workshop held with the research team, the Iowa DOT, local contractors, and design - consultants to develop improved methods to replace bridge deck expansion joints.

CHAPTER 2. DETERIORATION PATTERNS AND MAINTENANCE EFFORTS

2.1 Chapter Overview

This chapter details the results of interviews with Iowa DOT bridge leaders regarding their field experience with joint deterioration and the maintenance efforts they pursue to extend the life of the bridge deck expansion joints in their specific districts. This chapter is organized by type of expansion joint. Each joint section discusses identified patterns of deterioration, maintenance methods utilized in extending the life of the expansion joint, and the indications that the maintenance crew leaders use to determine when maintenance or replacement may soon be needed.

2.2 Introduction

The Iowa DOT doesn't have published guidelines that specifically state the maintenance to complete on expansion joints. Most actions are determined and completed at the discretion of the District engineer and the bridge maintenance crew leader. As such, the actions taken often remain largely unknown to the design engineers who will eventually be designing joint replacements.

2.3 Research Methodology

Deterioration patterns were documented primarily by field visits to Mark Carter, Iowa DOT District 6 Bridge Leader and a planned future visit to Greg Mize, Iowa DOT District 3 Bridge Crew Leader. At the writing of this report, the field visit with Greg Mize has been delayed due to heavy rainfall and flooding in the western portion of Iowa.

The maintenance efforts taken to correct deterioration patterns will be recorded during these field visits. Once both visits have been completed, interviews of the remaining bridge crew leaders will take place to verify the similarities between their operations and those of Districts 3 and 6 if deemed necessary by the technical advisory committee.

Four main groups of expansion joints were identified as being widely utilized by the Iowa DOT: sliding plate joints, strip seal and compression seal joints, modular and finger joints, and integral abutment joints. While other joint types have occasionally been utilized by the Iowa DOT, their usage was uncommon, largely untested, and not addressed during this study.

2.4 Sliding Plate Expansion Joints

A sliding plate expansion joint is a system with steel plates embedded in both the abutment side and deck side of an expansion joint that are then allowed to freely "slide" over one another to provide a smooth ride for traffic and allow for the required movement of the bridge deck.

Sliding plate expansion joints are no longer utilized by the Iowa DOT for new construction. However, of the 1,000 bridges on the primary system that contain expansion joints, about a third still contain at least one existing sliding plate joint (Jim Nelson Personal Communication Dec. 4, 2013). Thus, the maintenance and rehabilitation of these joints are still of major concern for the immediate future.

2.4.1 Joint Deterioration

At the advanced age of most of the sliding plate joints, several problems are generally occurring. Since most of the sliding plate joints are already experiencing these types of deterioration, the age at which these problems occur was not discussed. Among the most common observed by the Iowa DOT maintenance personnel is a lack of movement in the joints.

After many years of sliding against one another, the two plates that form the joint start building up rust in between the plates. Eventually the rust between the plates build up to such a degree that the plates are fused together and the joint becomes immobile. These now fixed joints prevent the bridge deck from expanding or contracting as necessary and cause additional stresses to build up in both the abutment and the bridge deck. When stresses in the concrete become high enough, the joint eventually pulls free from the surrounding concrete.

According to Mark Carter, when the joints pull free they generally pull free from the abutment side of the joint. The damage can be anywhere from simply a steel plate pulling loose and needing removed from the joint to the extreme case where the abutment fails at its base where it connects the footing. The severity of the damage is usually somewhere between these two cases with the steel plate and a large section of concrete, but not the entire abutment, pulling free. The opposite case where the joint pulls free from the deck side is considerably less common but still occurs.

A second major point of failure with sliding plate joints is fatiguing of the steel plate. This damage is especially likely to occur in areas with considerably heavy truck traffic, especially if that traffic has increased from when the joint was originally installed.

The combination of the plate losing structural section strength due to rust formation and the cyclical loads of heavy traffic eventually cause fatigue damage to the steel plate, and large sections of the plate may break loose as seen in Figure 2.1.



Image: Adam Miller, ISU

Figure 2.1. Large sections of a plate broken loose on northbound I-380 Exit 19A in Cedar Rapids, Iowa

The joint shown, now replaced, was present on Exit 19A, Northbound I-380 in Cedar Rapids. A processing plant was noted a few blocks from the exit and the Iowa DOT inspector had observed a considerable amount of heavy truck traffic on that exit. Most of the joints along that exit showed similar fatigue damage including one joint where nearly the entire top plate was missing.

2.4.2 Signs of Joint Failure

There are a few signs of an immobile joint that is pulling free from the abutment. The first sign is a gap gradually forming between the top of the abutment and the approach slab as shown in Figure 2.2.



Image: Trevor Otto, ISU

Figure 2.2. Gap forming between top of abutment and approach panel on the I-80 over I-35 west abutment

Notice there is a gap (which is also filled with debris) forming between the approach panel and the top of the abutment. When initially constructed, these two slabs should be flush with only a small bond breaker between the panels.

Noise produced when driving over the joint can be another sign of joint failure. A sliding plate joint that is in good condition should make little noise when traffic passes over it. However, if the joint has pulled loose from the abutment, there is a sound described by Mark Carter as sounding “like a cannon being fired.” The louder the noise, the more movement is occurring in the joint.

Signs of fatigue damage are typical for many steel structures that are subjected to repetitive loads. Cracks along an expansion joint are important indications of incipient plate failure. Vertical movement of the top plate of the expansion joint can also be observed during the passage of traffic. There can, however, be some difficulties in observing fatigue cracks in the plate.

In past decades, joints were not always replaced as a part of a typical bridge overlay job. To match the new grade of the bridge deck to the grade of the expansion joint, a second steel plate, known as a raise plate, was welded to the top plate of the existing joint. While this solved the elevation problem, it did not add any structural capability to the steel plate.

Years later, the original top plates are now beginning to fatigue, but the damage is hidden under a raise plate that usually appears to be in relatively good condition. This can be seen in Figure 2.3 (before replacement), where a badly rusted top plate can be viewed beneath a top plate showing relatively good conditions.

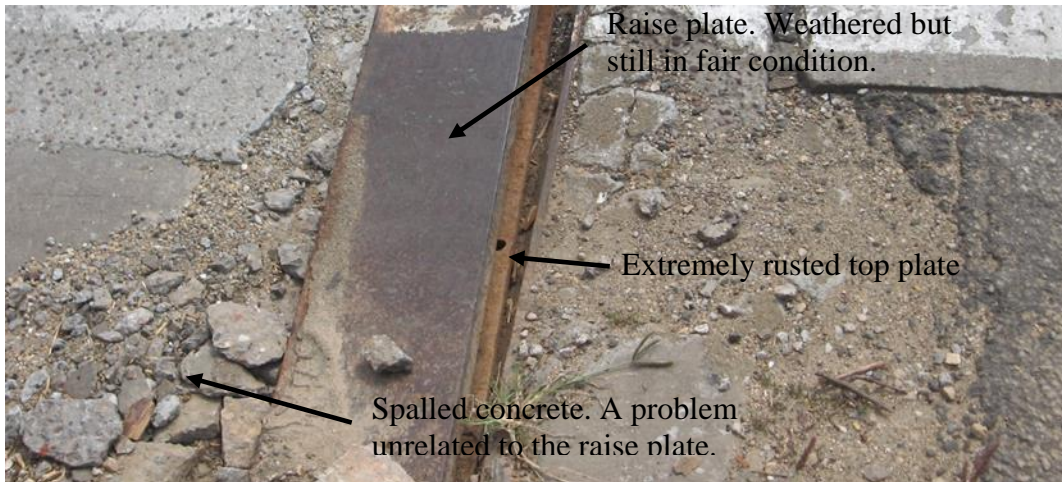


Image: Adam Miller, ISU

Figure 2.3. Rusted top plate beneath a raise plate showing relatively good condition on westbound US 20 over Catfish Creek in Cedar Rapids, Iowa

The portion shown is along the shoulder section of the highway. The top plate had come loose previously and been removed across the entire two lanes of traffic of the joint.

2.4.3 Joint Maintenance Efforts

There are several aspects to consider when maintaining sliding plate expansion joints. These joints are not and never were designed to be watertight. Thus, maintenance measures never considered the need to make the joint watertight. Improving the joint beyond the original condition was considered to be out of scope of maintenance efforts. Secondly, the main purpose is to allow the expansion and contraction of a bridge deck to prevent structural damage. Thus, the main goals in repairs of sliding plate expansion joints is to allow for the movement of the bridge deck and the passage of traffic while disregarding whether the joint prevents the passage of water.

Damage where the joint has pulled loose from the abutment, or less commonly the bridge deck, is problematic. Such damage generally involves the removal of a substantial amount of concrete requiring a period of traffic closure to complete the repairs. These traffic closures are sudden and generally occur at a less than ideal time, requiring the roadway to be opened again in a rather short amount of time. To do this, the loose concrete and joint sections are removed in their entirety. The missing concrete and joint are then replaced by creating a flat open joint in the roadway. Essentially, the concrete is removed and new concrete is placed with a gap between the abutment and bridge deck allowing for bridge movement. An extreme case where both sides of the joint have broken loose is shown in Figure 2.4



Image: Adam Miller, ISU

Figure 2.4. Extreme case of sliding plate joint maintenance

The gap in the joint appears small because the photo was taken on a summer day when the bridge was very near its expansion limit. This situation will likely not provide a smooth riding surface over the joint, but it still achieves the purpose of allowing for the movement of the bridge deck and the passage of traffic while still allowing the passage of water.

Under the short duration of the closures, placing a new joint is not a feasible option. This repair may not create a good joint, but it is a functional solution in the time allowed and will not allow significantly more damage from water passage than previously allowed.

In the case of fatigue damage where sections of the plate steel breaks off, a feasible repair strategy has not been identified. Mark Carter described in detail attempts to repair these joints to a like-new condition by welding in place replacement sections of plate steel. However, despite the considerable efforts to weld and reinforce these problematic sections of steel, the difficulty of providing a field weld of sufficient quality in these sections usually proved such repairs to be short-lived and the plate would soon be loose again.

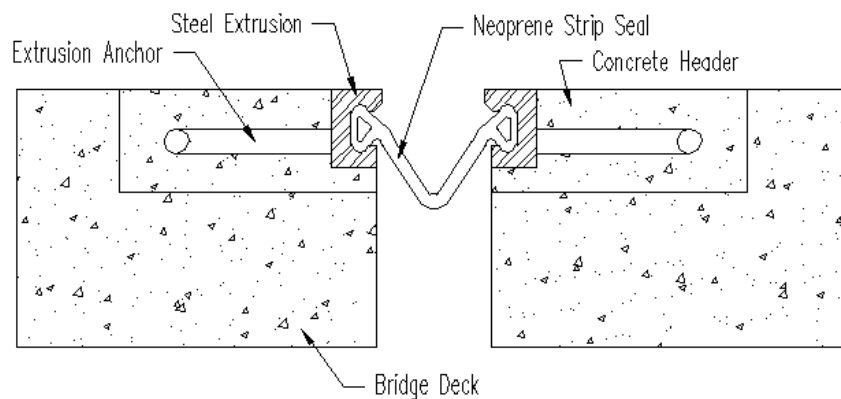
When plates have fatigued and broken loose, they are monitored until the plate is loose enough to allow easy removal. Waiting to remove the failing section of plate can be beneficial for maintenance personnel. However, while a plate that has only just begun to crack and fail can be extremely difficult to remove, a plate that is extremely loose has the potential to fail entirely and become a hazard to traffic.

Maintenance personnel monitor the joint for that perfect time when removal of the loose plate will be easy, but it is not yet in danger of disrupting traffic. The repair shown previously in

Figure 2.1 would be typical of what remains of a plate joint. The joint will no longer provide a smooth ride for traffic, but will still complete the main functions of allowing the movement of the bridge deck and the passage of traffic.

2.5 Strip Seal and Compression Seal Joints

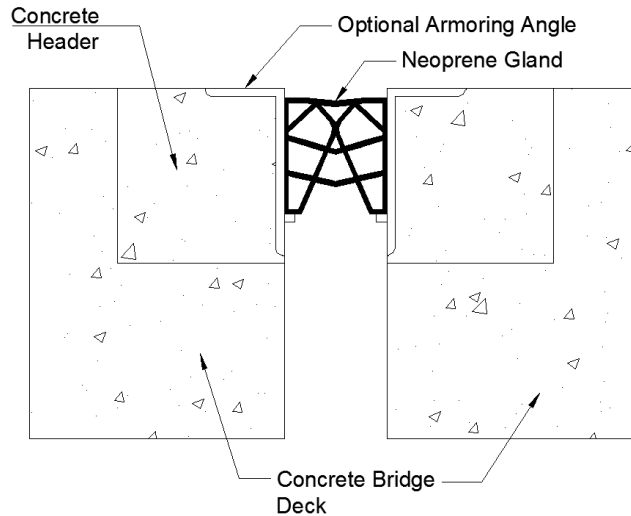
Strip seal and compression seal expansion joints are separate styles of joints that utilize a gland to prevent the passage of water through the expansion joint. In particular, a strip seal joint includes a gland, generally neoprene, that is mechanically locked in place through the use of steel extrusions embedded in the concrete header on either side of the expansion joint. An example of a strip seal joint is shown in Figure 2.5.



Not to scale. Drawing: Adam Miller, ISU; adapted from D.S. Brown Company (dsbrown.com)

Figure 2.5. Strip seal joint

A compression seal is forced into place and uses the compressive force from the bridge deck to remain in place as seen in Figure 2.6.



Not to scale. Drawing: Adam Miller, ISU; adapted from Watson Bowman Acme Corp. (wbacorp.com)

Figure 2.6. Compression seal joint

Although the Iowa DOT is phasing out the use of compression seals, they are still installed occasionally and a considerable number are currently in use. Both strip seals and compression seals have similar deterioration patterns and are addressed together in the next section.

2.5.1 Joint Deterioration

The most common problem with strip seal and compression seal joints is the failure of the neoprene glands that are placed in the joints. In Iowa, this typically occurs after about 15 years of service for a strip seal joint and 10 years of service for a compression seal joint.

A failed seal is not a failure of the structural integrity of the joint. as the seal is not a structural component. The seal is simply in place for waterproofing purposes. Thus, failure of the seal allows the joint to still function, movement of the bridge deck will still occur, and traffic is not hindered, but the joint will now allow the passage of salt and deicing chemicals that may damage the substructure.

Both strip seal and compression seal joints have problems with debris building up in the seals, as seen in Figure 2.7.



Image: Adam Miller, ISU

Figure 2.7. Badly weathered, but still functioning, strip seal joint

This buildup causes a number of problems. The abrasive nature of the collected materials causes additional wear to the neoprene seals. Additionally, this buildup may prevent the expansion joint from closing properly during warm summer months. The material essentially decreases the allowable expansion distance. This can cause additional stresses to build up in the end of the bridge deck during warm summer months.

Strip seals and compression seals also suffer from spalling of the concrete immediately on either side of the expansion joint. Spalls by themselves are often not severe enough to cause joint failure. They do, however, lead to other problems. Spalls allow water and corrosive chemicals to penetrate more easily to the reinforcing bars at the end of the bridge deck. This may eventually lead to larger spalls and weakened concrete holding the joint in place. Water may also begin to penetrate the interface between the concrete and the joint. Eventually, the back of the joint can begin to rust as can be seen in Figure 2.7 above.

Expansive force due to the formation of pack rust can force the joint forward. Additional stresses are then placed on the joint anchorages, which, when coupled with normal traffic loading, can then separate from the extrusion.

Mark Carter had on hand several examples of joints where the extrusion pulled free from the extrusion anchor at the weld that connects the two. This tipping forward of the joints also makes them more susceptible to snowplow damage by creating a small ledge that can be caught by the blade.

Rust is commonly only a problem in the interface between the joint and the concrete. However, on a rare occasion, and with an extremely old steel extrusion, rust may form inside the extrusion preventing the neoprene seal from being inserted. Rust inside the extrusion almost always occurs in a seal that has served its useful life and already requires a replacement. This problem is essentially the same in modular joints (and can be seen later in Figure 2.14).

Failure of extrusion sections in Iowa by snowplow damage, traffic loading, or otherwise early in the lifespan of the joints are not common and are usually considered to be a result of faulty installation.

Unique to compression seals, sections of the steel armoring may fracture under traffic loading. Failure of the steel armoring is particularly common in the wheel path. After the loose armoring is removed, the concrete below is often revealed to have been inadequately consolidated. The inadequate consolidation results in a series of voids beneath the steel armor causing a significant increase in stress that the steel armoring is not intended to resist. After enough loading cycles, sections of armoring eventually fail, fracture, and come loose. Loss of the steel armoring is generally not a major point of joint failure by itself and can be repaired easily. However, the failure of the steel armor is, in general, a sign that the joint is rapidly approaching the end of its useful life and will likely need a major repair or replacement in the next few years.

2.5.2 Signs of Joint Failure

Failure of a strip seal joint and a compression seal joint is less apparent than it is with a sliding plate joint. The easiest way to tell if a gland has failed is by visually inspecting the gland for tears and punctures. However, failure of the neoprene glands can be difficult to observe visually if the failure is still small. Debris collected in the joint will exacerbate the difficulty of seeing the failure visually.

Joint leakage can also be determined from the effects on the underside of the bridge. Rusted substructure components, debris buildup, and visible moisture, particularly after rain, on the underside of the bridge deck are all signs that the seal may have failed. However, these are general signs of a leaking joint and could very well be other problems aside from a failed gland.

In the case of rust, it can be difficult to see the extent of the damage visually until it has reached a severe level. It can be particularly difficult to tell if a joint has become misaligned due to rust buildup between the joint and the bridge deck.

Rust tends to force the top of the joint forward. When strip seal extrusions are initially constructed they are set with the top surface parallel on both extrusions. Ideally, the top surface is also parallel to the bridge deck. The same applies to compression seal armoring. Thus, the amount of movement can be roughly estimated from the misalignment of the joint. However, it can be difficult to observe the extent of the joint movement.

One trick that Mark Carter uses is to place any flat straight object (an engineer's scale was used during the investigation) perpendicular to the joint extrusions and sighting down the joint. It will then be much easier to determine to what extent the joint has moved relative to the bridge deck and to the opposite extrusion. This trick provides a simple, although not perfect, method of estimating the extent of the damage from the joint alignment visually.

Signs of concrete spalls are more difficult to observe before damage becomes visible. Hammer tapping, such as that described in the American Society for Testing and Materials (ASTM) ASTM D 4580, remains one of the best methods for determining the state of concrete delamination. However, the Iowa DOT Office of Maintenance generally ignores concrete spalls in the joint header until the damage is visible.

Diagrams of joint components can be found previously in Figure 2.5 and Figure 2.6. Note that generally ignoring concrete spalls in the joint header until the damage is visible only applies to Iowa DOT maintenance of joint headers and does not include deck repairs or contracted work. Spalls of small areas such as concrete headers are just not economical to test regularly until the damage shows.

Signs of fatigue for steel expansion joint parts are typical of those for any steel member. Cracks and unintended movement of the steel armoring are the most noticeable signs of fatigue failure.

2.5.3 Joint Maintenance Efforts

There are a variety of maintenance efforts that can be undertaken to correct the previously discussed deterioration. The simplest problem to solve would appear to be the collection of debris in the seal. One solution is to apply compressed air or pressurized water at regular time intervals and remove the debris from the joints.

It is estimated that joints ideally require cleaning twice during the spring and summer months. It is unnecessary during the winter as the joints are generally in a more open position and, therefore, less likely to have issues with debris blocking expansion movement as the bridges contract. In addition, it is during winter that a lot of the debris, particularly from sand and salts applied to the road during winter weather, accumulates. However, joint cleaning is not universally performed by the Iowa DOT.

In District 6, specifically, debris is only removed when other work is being completed on or nearby a joint. The given reason for this shortfall in maintenance is a lack of labor because the maintenance offices do not have enough labor to spare man hours for cleaning debris out of expansion joints.

A lot of discussion was present during our investigation on the problem of debris collecting in expansion joints. The literature reviewed during the literature review also commonly discussed this problem. Mark Carter's suggested solution for this problem was to contract out joint cleaning on a yearly basis. The cleaning of the joints could be hard bid similar to bridge painting or other contracted maintenance repairs. This could address the problem without diverting Iowa DOT maintenance staff from other projects.

A second suggestion, from Chang and Lee (2002), is to allow water and debris to drain from the end of the joint. If the joint is then placed with a great enough cross slope, debris should be washed out of the joint during rain storms. This would eliminate the need for labor, contracted or

in-house, to clean out the joint. However, Mark pointed out that a strong wind could blow this contaminated water onto the substructure of the bridge, potentially causing the same damage the joint is intended to prevent. So, while this idea has merit, it is not nearly as simple as suggested and would require some form of drainage system to work properly and protect the substructure.

Broken and failed seals are also rather straight-forward to fix. In most cases, a failed seal can simply be removed, the extrusions cleaned, and a new seal installed. It is allowed by the Iowa DOT to simply remove the failed portion of the neoprene seal and splice in a new section. However, in the Iowa DOT's experience, it has been found that the repairs last longer if an entirely new seal is installed across the entire joint.

Field splices in the neoprene strip seal are difficult to properly construct and are prone to early failure between the old and new sections. Thus, it is suggested that field splices should be used on the neoprene joints only when absolutely required to replace the seal. Typically in Iowa, neoprene seal replacements are contracted out and not completed by the Iowa DOT.

Spalls are most commonly repaired by removing the loose concrete and patching the spalls with new concrete or asphalt. These repairs can generally be performed quickly with little traffic disruption. Cure time for the concrete patch tends to be the longest part of these jobs. Traffic disruptions for these repairs could be made even shorter with a faster curing, yet still durable concrete mix to use for patching. As well, it was stated that spalls should be repaired as soon as possible after they appear, to prevent further damage of the reinforcement and steel joint components from chloride penetration.

Despite the best efforts to prevent damage to the strip seal extrusions, it is common for them to see severe damage toward the end of their lifespan. Despite the use of corrosion-resistant steel, it is typical for joints to have considerable rust buildup toward the end of their useful life. As the rust buildup is often between the steel extrusion and concrete header, there appears to be little that can be done in terms of maintenance to address this issue. It is likely that a section of the steel extrusion will eventually be torn loose from the rest of the joint.

Loose sections of extrusion are fully repaired only if the damage is done in the early stages of the joint life cycle. If the joint is old, it will likely be programmed for replacement and little more action taken. If the failure is early, repairs will be necessary to avoid further damage to the bridge substructure.

Several different repairs for extrusions were examined during the investigation. Figure 2.8 shows a strip seal joint with a missing section of the extrusion.



Image: Adam Miller, ISU

Figure 2.8. Strip seal joint with missing extrusion section

The considerable rust between the joint and header concrete leads to the conclusion that this section of extrusion was probably pulled free from the anchors. The forward movement of the joint likely allowed a snowplow blade to catch the extrusion and pull it free. If the joint was still fairly new, concrete may be removed to allow a new section of the extrusion to be embedded and field welded to the existing sections.

Maintenance personnel cautioned that if only a new section of the extrusion, and not an entire new extrusion across the bridge deck, is to be installed, the section should extend from the failed section to the edge of the bridge. In other words, there should only be one point of contact between the old and new sections of joints. It was their experience that a new section of extrusion placed between two existing sections tended to buckle during hot weather. The buckling combined with normal traffic loading often fatigued the field welds quickly on either end, and the welds would soon fail. While the extrusion should still be embedded into the concrete, the broken welds allow water to flow through the joint rendering the repair ineffective. As well, the splice weld should avoid the wheel path of the bridge, even if doing so requires removing a larger section of the broken extrusion than otherwise be necessary.

However, in Figure 2.8, it is apparent that no new section of extrusion has been installed. It was judged that this joint is old enough that replacing the missing section was not economical. That being true, the joint, while extremely worn and showing several signs of coming failure, was not in bad enough condition to warrant a full replacement of the entire joint yet. Instead, District 6 maintenance staff created their own temporary fix.

The loose section of extrusion was removed but the neoprene seal was left intact. Two bolts were doweled and epoxied into the deck to provide a mechanical attachment for the seal. An adhesive

was then used to both hold the neoprene seal against the concrete and to again create a watertight seal where the extrusion was now missing. This repair had been in place for several years and, with occasional maintenance, this repair was performing at an acceptable level.

Broken sections of compression seal armoring are fixed much in the same way that sliding plate joints are fixed, by replacing the broken armoring, and any loose concrete, with new concrete to provide a flat, smooth riding surface. In this situation, compression seals have the advantage of still maintaining a well-functioning seal provided the concrete header is still largely in good condition and there is no damage to the neoprene gland. The steel armoring is merely present to protect the concrete edge and increase the durability of the joint. The armoring does not actually contribute to the ability of a joint to be watertight or accommodate expansion and contraction. This type of repair is shown in Figure 2.9

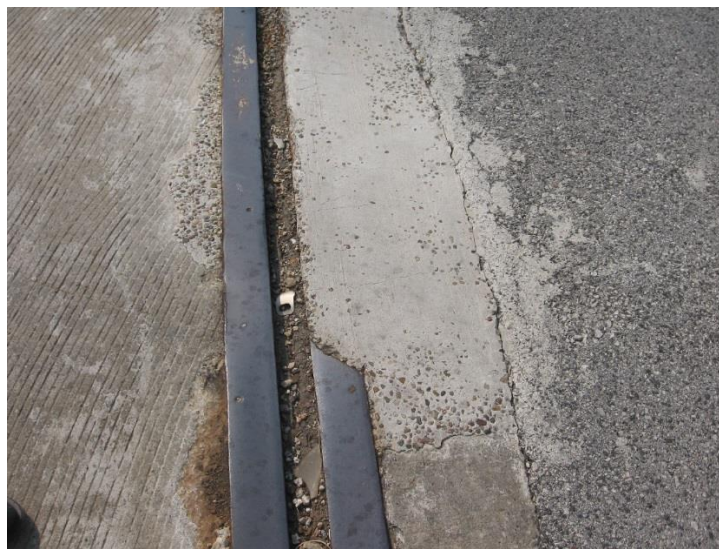
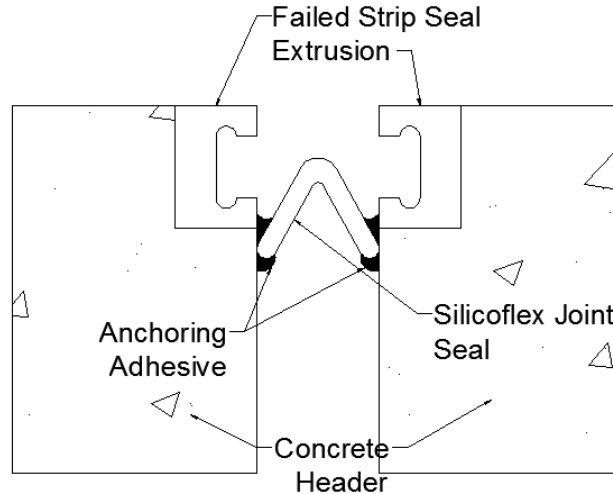


Image: Adam Miller, ISU

Figure 2.9. Compression seal joint with failed section of armoring

These repairs tend to be completed in several hours as there is no major removal of concrete involved. The longest schedule element is the required cure time for the new concrete.

Recently, the Iowa DOT has been experimenting with the use of a Silicoflex joint sealing system from R.J. Watson, Inc. as a repair measure for damaged expansion joints. A Silicoflex seal is essentially an inverted strip seal held in place by an adhesive instead of an extrusion. The use of an adhesive makes Silicoflex ideal for joint repairs involving damaged strip seal extrusion sections. An example of a repair done with a Silicoflex Joint is shown in Figure 2.10.



Drawing: Adam Miller, ISU; adapted from R.J. Watson, Inc.
 (www.rjwatson.com/wp-content/uploads/silicoflex-brochure-may.pdf)

Figure 2.10. Silicoflex expansion joint example

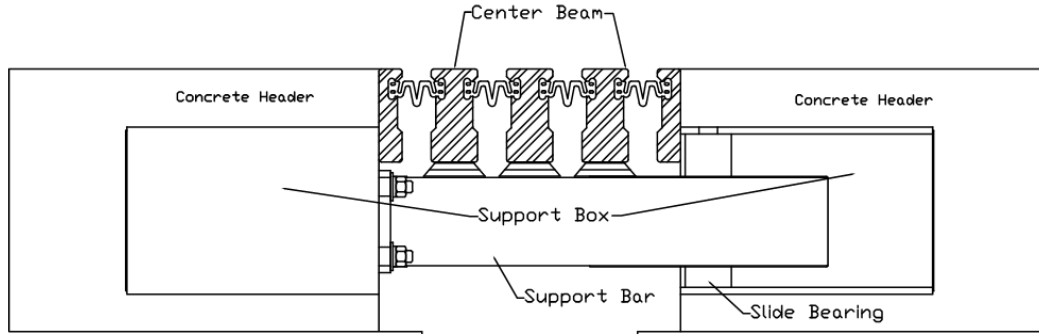
The seal can be attached to any flat vertical face of the joint. This means there is no need for concrete demolition, and no need to remove any existing steel sections of the joint. The new seal can be attached directly with the adhesive below the existing sections of extrusion. Major concrete damage to the vertical face will still require repair to allow a bonding surface for the Silicoflex joint.

The lack of any major removal, lack of concrete construction, little to no cure time, and the ease of installation makes this a very quick and cheap joint to install. The manufacturer brochure estimates less than 30 minutes for installation per lane, assuming that the only construction task is the joint installation, with the possibility of the bridge opening about an hour after the end of the installation (R.J. Watson).

To date, this joint had been used on at least two repair projects in Iowa, one of which had experienced a major early loss of a large section of the existing strip seal extrusion. As of the writing of this report, the first annual inspection of this joint had not been completed on either of these projects. Durability and functionality information will be included in a later phase report provided that it becomes available.

2.6 Finger Joints and Modular Expansion Joints

Finger joints and modular expansion joints are styles used by the Iowa DOT for large expansion distances, typically greater than 5 inches. Finger joints, as the name suggests, are designed as a series of interlocking steel fingers used to transfer traffic across the joint. Modular expansion joints are essentially a series of strip seal joints supported by steel support bars placed parallel to traffic as shown in Figure 2.11.



Drawing: Adam Miller, ISU; adapted from D.S. Brown Company
 (dsbrown.com/Resources/Bridges/Steelflex/Joints/D320-PV-S.pdf)

Figure 2.11. Modular expansion joint

Currently, the Iowa DOT tends to favor finger joints for large expansion distances. However, there are still several modular joints installed on bridges in Iowa.

2.6.1 Joint Deterioration

There was much less discussion with Mark Carter about finger and modular joints than about the other joint styles. This is not surprising as there are only 58 bridges in Iowa with finger joints installed compared to almost 400 bridges still utilizing sliding plate joints and more than 500 bridges utilizing strip seal joints. Because there are fewer of these types of joints, it follows that mean less time is spent maintaining those joints and there were, in general, few problems with finger joints to begin with.

Since finger joints are not watertight, debris tends to pass through the joint without causing trouble to the joint. In addition, the nearly continuous riding surface prevents most all damage from snowplows catching raised edges of the joint. In fact, the only real problems that were given for finger joints included spalling of the header concrete, which is a problem that is typical of almost all joint styles, and the rare failure of one of the joint fingers. The structural failure of a finger can generally be traced to heavy traffic loads, especially if average daily traffic has increased since the initial design and installation of the joint.

The one major disadvantage of finger joints is that they are not watertight and, thus, typically require that neoprene troughs be installed below the joint to catch the water and debris that flow through the joint and divert them from the structural members. Problems with finger joints can usually stem from this neoprene trough. The first problem with these troughs is associated with the neoprene tearing near the trough anchors to the bridge deck, which allows the trough to fall loose. This was said to be particularly prevalent near the end of the winter months due to ice building up in the troughs. Snow and ice on top of the roadway melts during the day and then freezes again at night. However, in the shaded parts beneath the bridge deck, the ice doesn't melt, forming heavier and heavier loads that can eventually tear the trough loose.

Another problem relating to these troughs is the flow of water. Where strip seal, compression seal, and modular joints prevent water from passing through the joint entirely, finger joints merely divert the water after it flows through the joint. Some troughs divert water away from the center of the abutment, while a neoprene trough below a finger expansion joint, as shown in Figure 2.12, diverts water to a catch basin at the center of the footing.



Image: Adam Miller, ISU

Figure 2.12. Neoprene trough below finger expansion joint

The water should then flow harmlessly into the stream below without damaging the steel components of the substructure. However, many older Iowa bridges have no form of slope protection on the slope beneath the bridge. During periods of heavy rain, this continued water flow may eventually erode away the slope exposing the steel piling as seen in Figure 2.13. At least two pilings were exposed when the image in Figure 2.13 was captured.



Image: Adam Miller, ISU

Figure 2.13. Exposed piling from slope erosion

Modular expansion joints show many of the same problems that strip seal joints show. Neoprene glands again begin to fail at about year 15 and, as shown in Figure 2.14, incompressible debris collects in the joint.



Image: Adam Miller, ISU

Figure 2.14. Debris collection in modular expansion joint preventing full closure of the joint

Figure 2.14 shows the problem of debris preventing full closure of the joint particularly well, as it was taken on an extremely warm summer day. Most joints had already been or were nearly completely closed.

Concrete spalls are also quite common in modular joints. It has been found that in almost every case, spalls occur over the location of the support boxes, the steel boxes creating openings in the bridge deck for the support beams to rest, at between 9 and 11 years of age. This is very exact in comparison to most other joint styles that tend to spall at random points along the length of the joint from about 10 years until the joint is replaced.

Figure 2.14 also shows the problem of rust formation inside the steel extrusion, as was first mentioned with strip seal joints in Section 2.5.1. The left seal is not inserted into the center beam in this figure and is thus allowing a small amount of waterflow through the joint. This was explained to not be a common occurrence and that it only occurs on extremely old expansion joints. This particular joint was more than 30 years old and the neoprene seals had been replaced twice. It was found during the last neoprene seal replacement that there was just too much rust in that section of the center beam to fit the neoprene seal in place.

Given that the neoprene is held in place by the compressive action of the steel extrusion, the neoprene seals can already be difficult to install. If that compressive area is reduced even more, it can become impossible to install. Since the joint is already quite old, no major maintenance measures were taken. At this age, the joint needs to be replaced because any maintenance efforts would be ineffective and cause unnecessary traffic interruptions.

There are few visual indications of deterioration for finger joints. Tearing of the neoprene trough is extremely difficult to see as the troughs are often anchored to the bridge deck. Soil erosion problems may be detected by watching for places where the soil has washed away.

2.6.2 Joint Maintenance Efforts

Maintenance efforts for finger joints are rather straightforward. When neoprene troughs break, they are replaced with new troughs. Splices are allowed but, like neoprene glands, splices are not suggested unless absolutely required.

Erosion is addressed by replacing the eroded soil and compacting the new soil as well as possible. Erosion fabric may be placed, but is not done universally. Ideally, rip rap is placed on the eroding slope to help prevent further damage, but this is rarely done due to the expense and time required.

Fractured fingers in finger joints are generally ignored if an isolated case on the joint. In the past, it may have been attempted to weld the damaged section back to the existing joint but, like sliding plate joints, the welds tended to just fail again.

All in all, finger joints tend to require little actual maintenance between installation and replacement. However, finger joints also tend to be more expensive for initial installation and replacement due to the large amount of steel used in the joint.

Modular joints are disliked by many engineers and are not commonly utilized by the Iowa DOT. The first modular joints installed had a tendency for abrupt early failure. The substantial number of modular joint failures eventually led to the commissioning of the National Cooperative Highway Research Program (NCHRP) Report 402 – Fatigue Design of Modular Bridge Expansion Joints. This study determined the major causes of failure and then outlined solutions to be taken, and notably that welds were often undersized and that fatigue damage was often not considered during design. Since the publication of this report, modular joints have improved considerably and are no longer prone to early failures. In fact, Mark Carter stated that modular joints were his preferred style, as the many components of the joint allowed pieces of the joint to be replaced instead of the entire joint.

Specifically in the maintenance of modular joints, like strip seal joints, torn neoprene glands are replaced. Although splices are allowed, they are still not suggested. Also, spacer springs beneath the joints are replaced regularly. These springs are used to ensure that the separate center beams are spaced evenly during bridge expansion and contraction. Their failure can be seen easily by bulging in the spring or the failure to return to their relaxed condition during the appropriate expansion or contraction.

Support beams are also painted occasionally to help prevent corrosion. It was cautioned that painters need to be extremely careful to keep paint off the sliding surface in the support box as this may prevent proper movement of the support beams. Other damage to modular joints is addressed in the same fashion as a strip seal joint.

2.7 Integral Abutment Joints

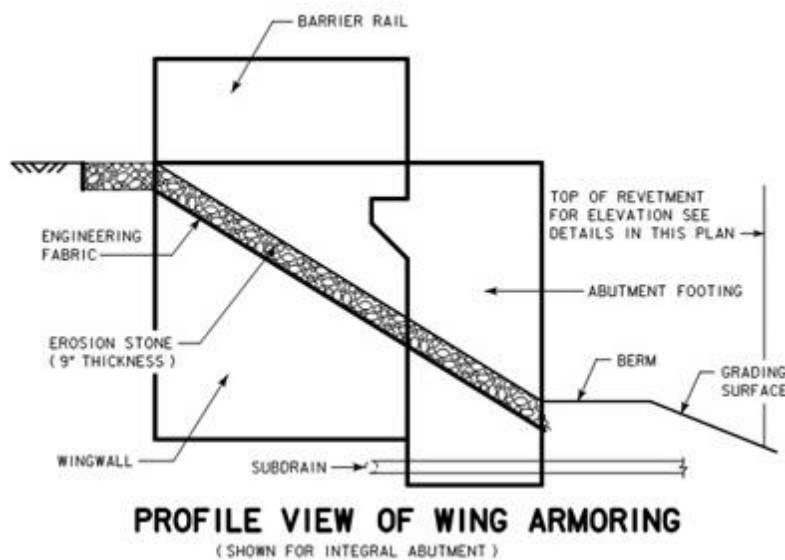
Integral abutment joints were examined only briefly in this investigation. Bridge Crew leaders stated that integral abutment joints were their preferred style of expansion joint because they are largely maintenance free. This preference in Iowa largely mirrored a survey of several other states conducted by Chang and Lee (2001) that reached a similar conclusion in the states surveyed.

There were only two main maintenance issues pointed out with regard to integral abutment joints. The first was the occasional patching of the tire buffing and silicon sealant (CF) joint used in Iowa to accommodate the movement between the abutment and the approach slab. The second problem dealt with erosion from the runoff at the end of the bridge.

The CF joint repairs are already quite rapid and very straightforward repairs. As expected with any crumb rubber and silicon joint, materials often break loose from the joint leaving voids for water to penetrate. To repair this joint, the loose and missing tire buffings are replaced and new silicon poured into the joint to provide a watertight seal. This is already a rapid and easy repair.

Erosion comes from the water runoff at the end of the bridge. During rainstorms, water flows over the joint, off the sides of the approach slab, and down around the abutment. Over a period of time, this water can wash away soil surrounding the abutment and eventually expose the pilings, similar to the situation described above pertaining to finger joints.

This erosion problem is known to Iowa DOT staff who are currently working on implementing a new detail for wing armoring on bridges. The detail for new bridges includes a bed of erosion stone atop a layer of engineering fabric atop the compacted subgrade and following the slope of the subgrade. This layer of stone should act as a drain allowing the runoff to quickly flow around the abutment and footing without eroding the supporting soils. A profile view of this new detail is shown in Figure 2.15. Erosion is repaired in the same fashion as it is for finger joints. Eroded soil is replaced, compacted, and monitored for any future problems.



Schematic: Iowa DOT

Figure 2.15. New Iowa DOT standard detail for wing wall armoring

CHAPTER 3. CURRENT JOINT REPLACEMENT PRACTICES

3.1 Chapter Overview

This chapter explains the details involved in two bridge deck expansion joint replacement projects that were observed during this first phase of the project. This chapter is organized by project. Each section provides an overview of information specific to each job and then provides pertinent observations that were made throughout the course of each project.

3.2 Introduction

In construction, challenges exist in communication and understanding between the design engineers and the workers completing the physical repairs in the field. Design changes can help expedite field work, but existing processes to replace expansion joints must be understood before changes can be made. Conversely, many jobsite supervisors may also have ideas that can facilitate more rapid completion of the repairs, but lack the engineering knowledge required to ensure that a design meets required standards for safety and durability. Thus, an objective of this chapter is to make engineers more intimate with the specific means and methods currently used during joint replacement projects.

3.3 Northbound I-380 Joint A Replacement

The Northbound I-380 joint replacement research targeted activities that occurred during the second year of a two-year project involving the complete removal and replacement of several expansion joints along I-380 through Cedar Rapids, Iowa. The joint replacement specifically observed, designated as Joint A, was immediately before Exit 19A on Northbound I-380 (see Figure 3.1).

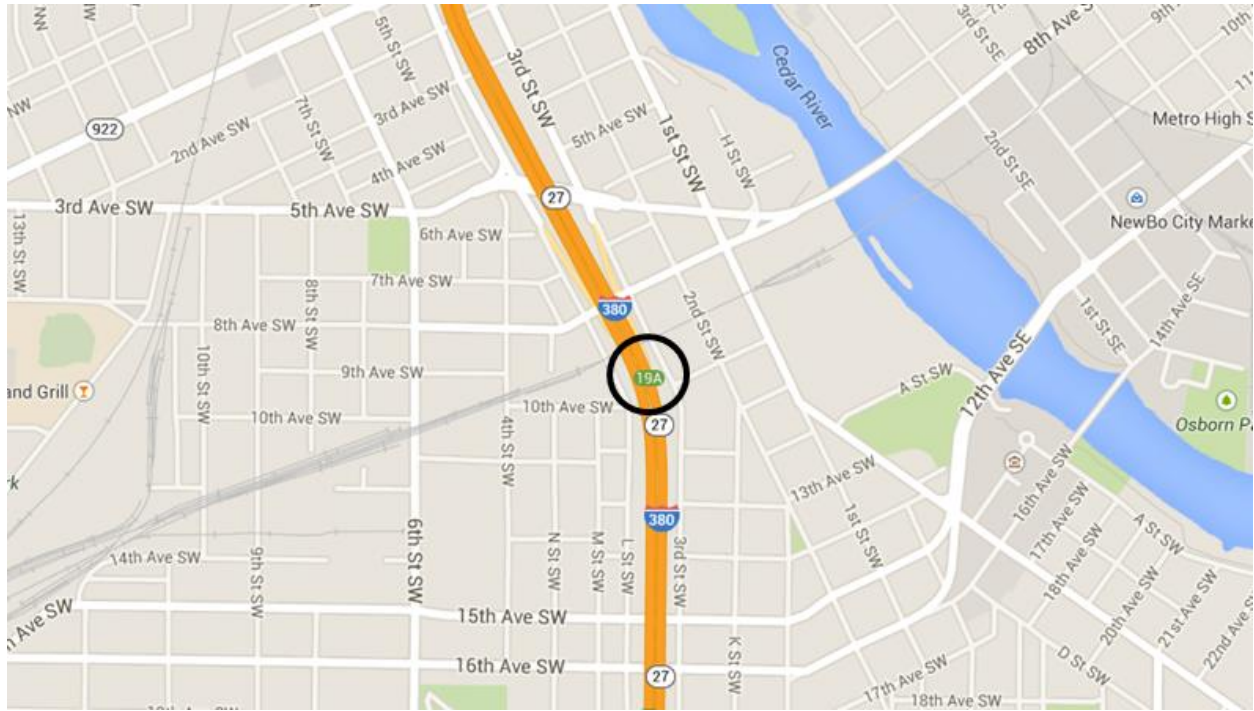


Image: © Google 2014

Figure 3.1. Northbound I-380 project location

Also along Exit 19A were joints D and E (see Figure 3.2).

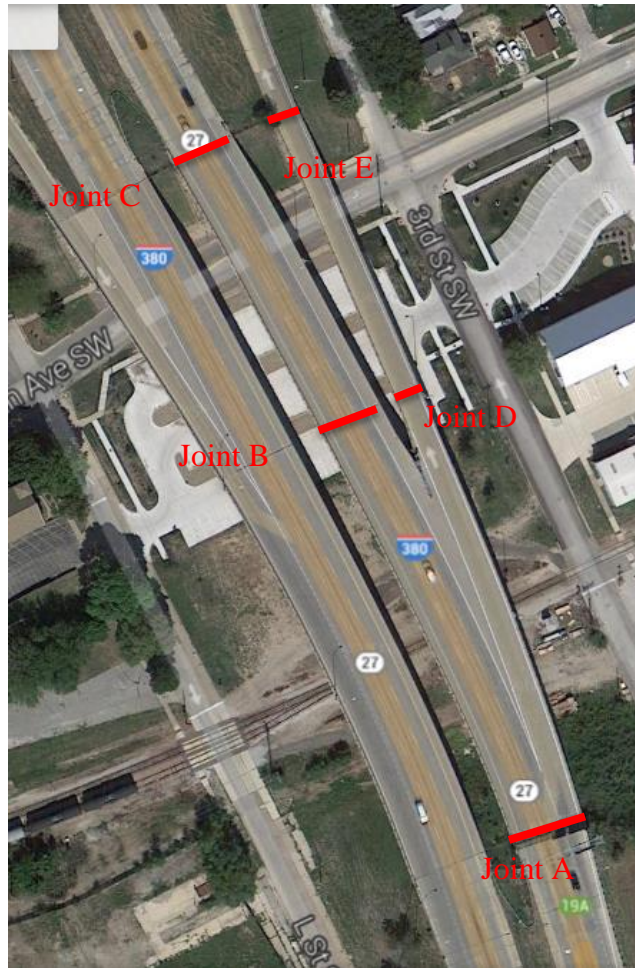


Image: © Google 2014

Figure 3.2. Approximate locations of expansion joints

In total, five expansion joints were to be replaced as part of this project over three consecutive weekends. Observations of the project were made during the first weekend. Detailed records were only kept for Joint A. However, some comparisons were also made throughout the project involving Joint D.

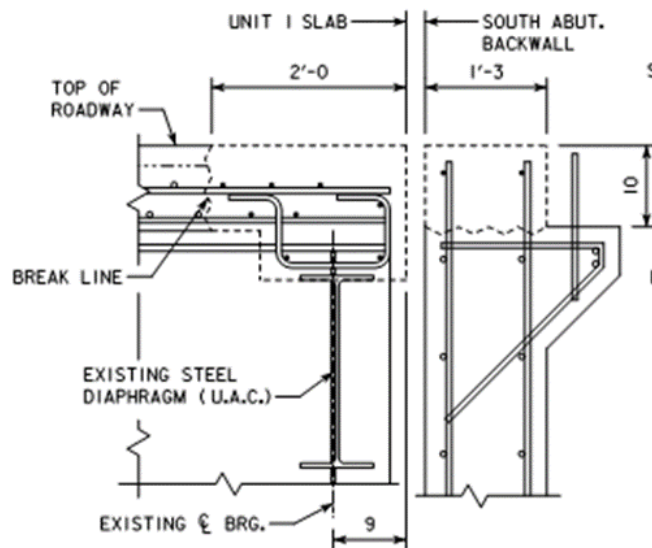
The initial staging during the first weekend of work entailed replacing both joints on the exit ramp, Joints D and E, as well as half of Joint A. The remaining half of Joint A, as well as Joint B and C, were replaced in sections over the next two weekends. With this staging plan, only the exit ramp would be entirely closed to traffic, and only for a single weekend. This closure could not be avoided due to the width of the ramp. For the remaining two weekends, at least one lane would always remain open.

3.3.1 Joint Condition and Replacement Plan

Joint A was an old sliding plate joint still in use long past its service life. Overall, the joint did not appear to be in extremely bad condition, because only an approximately one-foot long

section of plate had broken loose. However, when the top steel plate was removed, it revealed a considerable amount of rust that had built up. There was enough rust between the plates of the expansion joint that both the Iowa DOT inspector and the author doubted that the joint had been properly functioning in years. Not surprisingly, this rust buildup conforms to the joint deterioration patterns discussed previously in section 2.4.1 Other joints in this project, and Joint E in particular, exhibited much more severe failures that ultimately prompted the replacement.

The old sliding plate joint was to be replaced with a new strip seal expansion joint. Concrete removal would consist of the top of the backwall from the existing riding surface to the top of the paving notch and the end two feet of roadway concrete (see Figure 3.3).



Schematic: Iowa DOT

Figure 3.3 Typical I-380 concrete removal cross section

Unlike other joint replacements, this job did not require the removal or replacement of the approach slabs, paving notch, or the entirety of the backwall. Embedded rebar was to remain for the reconstruction of the joint. Any bars not embedded in the concrete were to be removed and replaced with epoxy-coated bars, which largely included the existing hoops and longitudinal bars. The new expansion joint and reinforcing steel (rebar) would be formed and constructed using a high early strength concrete mix. Previous tests on the concrete mix had resulted in the development of a maturity curve that indicated the required compressive strength of the concrete of 4,000 psi to be reached in 9 to 12 hours.

One of the main focuses for observing the replacement of Joint A was to find the length of time required to complete specific construction tasks. Knowing the typical length of a construction task greatly facilitates efforts to reduce the overall time of a joint replacement project. The longer the task, the more potential that task has for reducing the overall time of the project. If the task only takes a few hours, reducing that time is unlikely to shorten the entire project considerably.

3.3.2 Joint A Replacement and Methods

Traffic closures were allowed from 7:00 p.m. Friday evening until 6:00 a.m. Monday morning. Thus, traffic control measures started precisely at 7:00 p.m. Friday evening. Traffic control initially consisted of signage that directed traffic to change lanes, as well as traffic cones to designate closed lanes. The initial use of traffic cones allowed equipment mobilization to proceed as soon as possible after the 7:00 p.m. project start time.

On such projects where a considerable amount of work is done in a short amount of time, it is best to complete tasks concurrently with other tasks as often as possible. After traffic had been completely redirected out of the work zone, traffic cones were replaced with jersey barriers to increase the safety of the jobsite. As seen in Table 3.1 and Table 3.2, traffic control took about four hours of the project time to complete. However, since traffic control worked concurrently with equipment mobilization and demolition, it had little impact on the overall project time. Thus, the overall project time would not be reduced by reducing the time to install traffic control.

Table 3.1. Construction task length by hour

Date	7/19						7/20																		7/21																									
	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12								
Traffic control	■	■	■	■																																														
Equipment mobilization	■	■	■																																															
Hydrodemolition of Joint A				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																																
Demolition with 15-lb chipping hammers													■	■	■	■	■	■																																
Formwork and rebar placement																				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■										
Concrete placement and cure time																																																		

Table 3.2. Total construction task lengths

Activity	Total Hours
Traffic Control	4
Equipment Mobilization	2
Hydrodemolition of Joint A	14
Demolition with 15lb Chipping Hammers	6
Total Demolition Time	20
Formwork and Rebar Placement	13
Concrete Placement and Cure Time	11

3.3.2.1 Joint A Concrete Removal

Equipment mobilization began shortly after traffic was completely rerouted, which was about an hour into the project. This job was unique in that the contractor utilized hydrodemolition for the majority of the concrete removal on Joint A. The contractor utilized an Aqua Cutter from Aquajet Systems AB, similar to the one shown in Figure 3.4.



Image: Iowa DOT

Figure 3.4 Aqua Cutter hydrodemolition machine

This system requires not only the aqua cutter but also a water storage truck and several trailer-mounted pumps to provide the necessary water pressure. The contractor also mobilized several towable air compressors and several 15-lb chipping hammers.

The aqua jet equipment took several hours to set up and properly align with the limits of demolition before the contractor could begin cutting. While this happened, the steel plates that formed the existing expansion joint were removed with an oxy-acetylene torch. It was explained by the supervisor that the aqua cutter would not be able to remove any concrete below the steel. Thus, the more concrete that could be exposed, the less concrete that would need to be removed by hand.

A moveable cage, which was essentially a few aluminum fence posts with several layers of orange snow fence, was placed around the aqua cutter on three sides. It was explained that during demolition, small particles or broken concrete may be thrown into the air. The particles would be small, ejected with little force, and of no danger to the workers or observers. However, these small particles could potentially cause superficial damage to passing traffic and damage to passing traffic needed to be prevented.

Demolition with the aqua cutter started promptly at 10:30 p.m., but was stopped after a short time. It was discovered that, upon removing the bottom layer of concrete, the water jet was digging a trench in the ground beneath the bridge. This had been anticipated by the contractor as a potential problem and the delay was short while sections of scrap steel plate were placed beneath the sections that were to be removed. The demolition process then continued.

The aqua cutter had a demolition width of about 5 ft. After completing the removal between the required limits, the machine was moved to the side, realigned with the previous sections of demolition, and restarted. Hydrodemolition of Joint A took place for about 14 hours (see Figure 3.5).



Image: Adam Miller, ISU

Figure 3.5. Joint A after hydrodemolition

The aqua cutter was capable of removing most, but not all, of the concrete necessary to replace the joint. In particular, the aqua cutter could not remove the concrete within about 8 in. of the curb, as well as the curb itself. While not of concern to this project, this area near the curb may

be larger if the joint is at a skew to the curb. There was also a small section of concrete beneath the existing joint that could not be removed with the aqua cutter (see Figure 3.6).



Image: Iowa DOT

Figure 3.6 Concrete remaining after hydrodemolition

The remaining concrete was removed with 15-lb chipping hammers. This was much slower than the removal by hydrodemolition, but also consisted of concrete often in confined areas and corners. Removal with chipping hammers was about a 6-hour task, bringing the total time for demolition to 20 hours.

Removal of Joint D had been done with 15-lb chipping hammers until the water jet had finished on Joint A. At this point, about a third of Joint D had been removed with 15-lb chipping hammers. The water jet was then moved to Joint D to finish removal of that section, while the 15-lb chipping hammers were moved to Joint A to remove the remaining concrete.

3.3.2.2 Joint A Formwork and Reinforcing Placement

The formwork installation started when about half of the existing joint had been entirely removed. Formwork was not complicated for this project and consisted of plywood supported by 2x4 lumber. Some of the sections had been precut and preassembled to expedite the process of installing the formwork. The concrete profile was identical to the section to be removed (shown in Schematic: Iowa DOT

Figure 3.3), although the reinforcing steel (rebar) layout had changed slightly for the new joint. This rectangular layout was ideal, as it avoided the need to build formwork with any angles other

than 90°. Other shapes, such as the angled profile of many paving notches, are more time consuming to construct than simple rectangular sections. Formwork was all placed by hand as the sections were not large enough to require any additional equipment.

The installation of the new reinforcing bar proceeded shortly after the bottom sections of formwork had been placed and supported. Waiting until the forms are in place allows the reinforcing steel to be supported by the forms at the proper elevation, by the use of rebar chairs, and ensures that proper cover requirements are met the first time the rebar is installed.

On this particular job, the contractor had to install, then remove and reinstall the rebar several times before the layout was correct. Overall, the additional effort involved in installing the rebar probably added several hours to the project length. The Iowa DOT inspector commented that the workers appeared inexperienced with rebar placement.

The reinforcing steel (rebar) was placed and tied together by hand with epoxy-coated rebar tie wire. The expansion joint extrusion was set in place with the reinforcing bar. The joint extrusions were separated by a piece of three-quarter in. foam insulation and then clamped together. The foam insulation would maintain the proper spacing while the concrete was poured and was both compressive and easily removed in pieces if the deck was to undergo expansion before the insulation was removed.

While the reinforcing steel was being placed, the end sections of formwork and bulkheads, again constructed out of plywood and dimensioned lumber, were installed. Formwork and rebar installation finished in the early hours of the morning and no additional work was completed on Joint A until later in the morning when the concrete batch plant opened to provide concrete. At this point, Joint A would easily be finished before the set deadline as long as the concrete was delivered to the site at a reasonable time.

3.3.2.3 Joint A Concrete Placement and Finishing

Concrete placing and finishing was an easy task on this project. Concrete arrived at the site promptly at 10:00 a.m. A high-range water-reducing admixture, as well as other chemicals, were added to the concrete on site immediately before the concrete was placed. The engineer that designed the concrete mix stated that the concrete would begin to set initially about 25 minutes after the chemicals were added, with previous tests showing required strengths being achieved in about nine hours.

The concrete pour was much more organized than the rest of the project and the construction laborers appeared to be very experienced with concrete pours. Immediately before concrete was placed, a thin layer of grout was placed by hand on all existing concrete faces that would adjoin the new concrete. Concrete was then placed directly from the truck into the formwork and vibrated with a flexible shaft vibratory compactor as shown in Figure 3.7.



Image: Jacob Shaw, ISU

Figure 3.7. Flexible shaft vibratory compactor

Once the concrete was placed and vibrated, the clamps holding the joint extrusions in place were removed. Even though the concrete had not yet set, pressure of the concrete behind the extrusion would hold the joint against the insulation separator.

The concrete was then finished by hand, first with wooden floats and then with magnesium finishing trowels, to provide a nice smooth riding surface. Curing compound was sprayed on the surface of the concrete, and the joint was left to cure.

3.3.2.4 Conclusions and Discussions

Some conclusions were made during the observations of this jobsite. The conclusions were reached during downtimes during discussions between the research team, the Iowa DOT inspector, and the jobsite supervisor.

- Demolition was the single longest construction task with concrete cure time taking the second most amount of time
- There was no clearly obvious way to precast an expansion joint
- General formwork shapes could be prebuilt, but complete prebuilding of formwork is extremely difficult

The prebuilding of formwork was a particularly prevalent topic. The same contractor had completed an identical job on the southbound lanes of I-380 the summer before and had not pre-manufactured any formwork. To save time during the observed job, general formwork shapes had been pre-constructed before the job began.

The discussion focused on the possible use of a pre-manufactured steel form that could be erected much more quickly. However, this idea was discarded as nearly impossible because, even though the Iowa DOT provides standard profiles for bridge members, the final dimensions often vary slightly. It would take a substantial number of different forms to have a form that would work for almost every bridge. Thus, it was just easier, cheaper, and seemingly slower to use plywood formwork and construct a portion of it during the job.

3.4 US 18 over the Wapsipinicon River

The US 18 over the Wapsipinicon River project (see Figure 3.8) was a typical joint replacement job for the Iowa DOT.

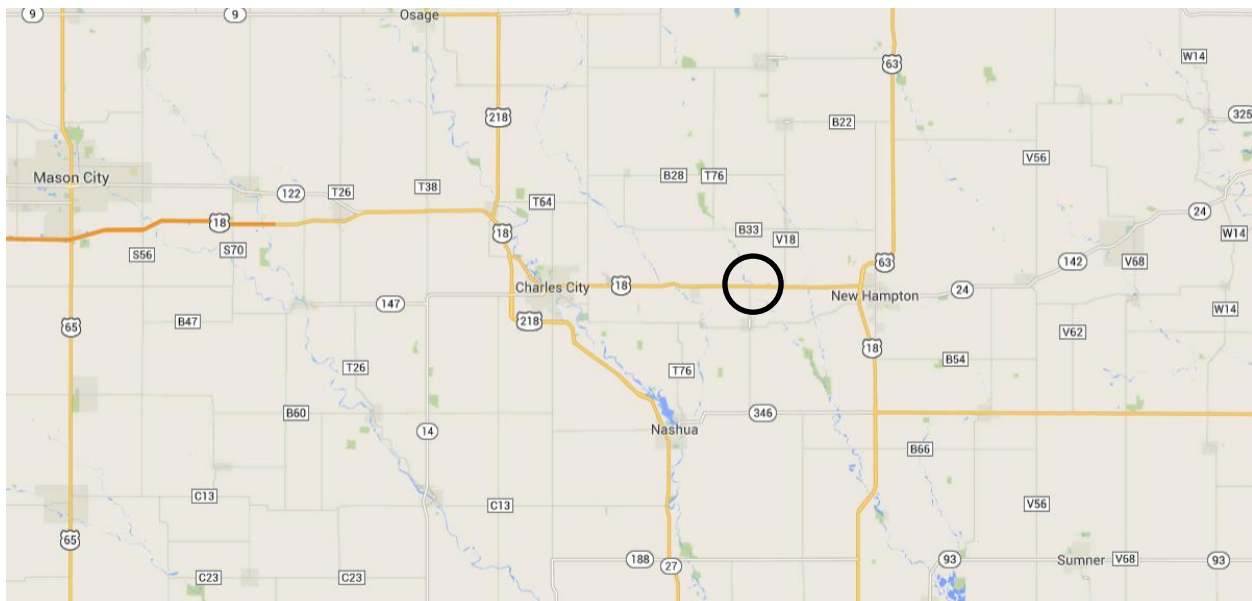


Image: © Google 2014

Figure 3.8. US 18 Over Wapsipinicon River project location

The project consisted of the removal and replacement of an existing sliding plate expansion joint with a new strip seal expansion joint at either end of the bridge. The replacement of the paving notch was also included in the construction and is a typical repair often included with expansion joint repairs. Detailed records of construction task lengths were not kept for this project, as the project took several months.

3.4.1 Joint Condition and Replacement Plan

When the site visit to US 18 was conducted, the existing sliding plate joints had already been removed from the bridge deck and abutment. However, the removed sliding plate joint sections were still present at the jobsite. The joint sections were badly rusted and had a significant number of broken plate sections. The bridge was originally built, including the old sliding plate joint, in 1978, making the existing joint almost 35 years old. There was not likely any particular circumstance that caused the joint to rust and fail. It was, quite frankly, just old.

This joint was set up as a typical replacement of a sliding plate joint with a new strip seal joint. Also included in the project were the removal and replacement of the paving notch, a portion of the abutment, and the doubly reinforced approach slab on both ends of the bridge.

Concrete removal was to consist of a 1-ft by 1-ft square section of concrete on the deck side of the joint along with the removal of the backwall to 1 ft 9in. below the bottom of the existing paving notch (see Figure 3.9).

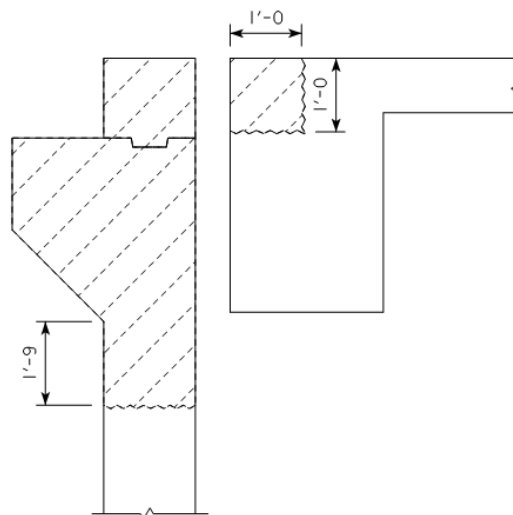
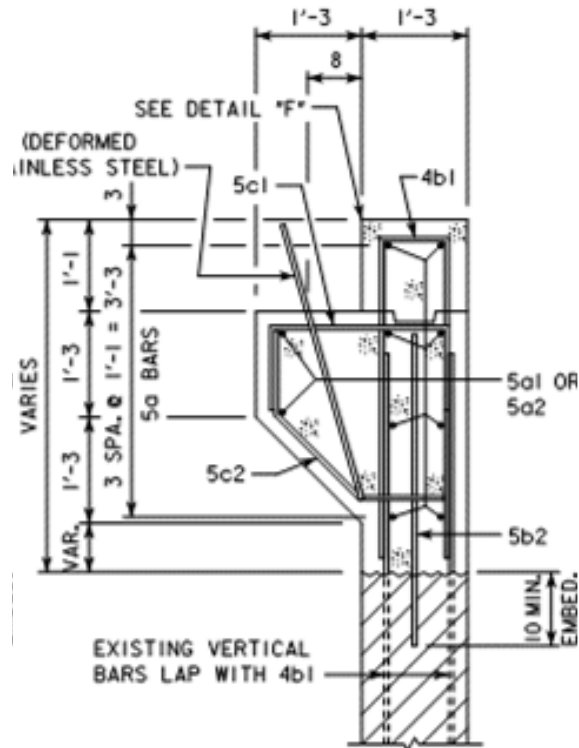


Figure 3.9. Typical US 18 removal cross section

On the deck side, any embedded longitudinal rebar was to be left in place for lap splices. On the abutment side, any embedded vertical bars were to remain. There was also an additional row of rebar doweled and epoxied into the remaining abutment to provide extra support (see Figure 3.10).



Schematic: Iowa DOT

Figure 3.10. Replacement paving notch plan

The US 18 job was given a contract length of 75 work days for completion. The job was constructed in three stages to provide one open lane of traffic at all times during the project.

Stage 1 consisted of the closure of the westbound lane and the construction of a paved asphalt shoulder on the westbound lane of the approaches. This paved shoulder effectively widened the westbound lane and allowed traffic to be routed partially onto the shoulder of the bridge, allowing a wider construction zone in the eastbound lane.

Stage 2 consisted of the reconstruction of the eastbound lane expansion joints, approaches, and the paving of the shoulder. During Stage 2, one lane of traffic was maintained on the westbound lane.

Stage 3 consisted of the reconstruction of the expansion joints and approaches on the westbound lane.

3.4.2 US 18 Observations

US 18 over the Wapsipinicon River was visited during the final stage of demolition of the joints. As is common, the bridge was staged so that one lane of traffic would remain open at all times. Thus, at this point, the entirety of the joint at the west abutment had been replaced and half of the

joint at the eastern abutment had been replaced. The second half of the eastern abutment was in the process of being demolished.

It had been noted during the I-380 observation that demolition seems to be the driving factor in how long a project takes. Thus, US 18 was observed during the demolition phase. The inspector noted that on the previous three sections, demolition had taken about three total days. After demolition, half of a day was usually required to straighten the vertical reinforcing bars that would remain embedded in the rebar.

It was observed that the existing horizontal bars on the deck side of the joint took little damage and could be efficiently removed with 15 lb chipping hammers. The backwall and paving notch had mass removal completed with a skid loader mounted hydraulic breaker. 15 lb chipping hammers were utilized to remove the final sections of the backwall to provide a relatively straight, smooth edge for reconstruction. Such detailed removal was not possible with a hydraulic breaker. Removal with the hydraulic breaker caused some small damage to the embedded reinforcing bar. However, this damage, mainly the bending of bars, was small and could easily be corrected after demolition.

As previously discussed, the biggest hindrance to faster demolition is the requirement that the existing vertical reinforcing bars in the backwall typically must remain in place to develop lap splices. Demolition would proceed faster with larger demolition equipment. However, larger hydraulic breakers would cause an unacceptable level of damage to the embedded reinforcing bar. If these reinforcing bars could be removed, the rate of demolition could be increased. The alternative to maintaining the embedded bars is to drill holes and epoxy new reinforcing bars into the existing footing. On some projects this would be an additional construction task and more equipment. However, on this and many projects the new abutment design required the addition of a third row of vertical reinforcing between the two existing rows. These bars can be seen in Schematic: Iowa DOT

Figure 3.10 above labeled as bar 5b2. In similar designs, there would be no additional step in the construction process, merely a step that would be lengthened while another is made shorter.

One observation that the research team found key was the use of a staged project instead of a detour to complete the US 18 job. As seen in Figure 3.11, the bridge of interest was only a few hundred feet beyond the intersection of US 18 and Iowa State Route V14 (Exeter Ave). This would be about a 2.5 mile detour to Iowa County Highway B57 that would meet US 18 in New Hampton, Iowa.



Image: Iowa DOT with detour route added by InTrans report authors

Figure 3.11. US 18 possible detour route

Using a detour would have allowed the bridge to be completely closed for the duration of the job. This would have eliminated the need to pave the approach shoulders and would have completely eliminated the work involved in the first stage of construction. From the contractor bid tabulation, the elimination of the first stage of construction alone would have likely saved \$60,000 or 13% of the overall cost of the job (Iowa DOT 2013). There would be other cost savings as a result in the reduction in traffic control requirements. Considerable time savings would result from the elimination of a construction stage, the reduction in time spent moving traffic control, reduced mobilization, and the elimination of about half of the necessary concrete pours.

There are a few negatives to using a detour. Motorists will be required to travel a slightly longer distance to reach their destination increasing user costs for travel such as fuel consumption and vehicle wear. The county roads utilized for the detour will also undergo increased wear for the period of the detour and the roads were likely designed for less average daily traffic (ADT) than the closed highway. The Iowa DOT will be liable to pay for the county maintenance measures required as a result of this increased wear. Bridge repairs are evaluated for the cost of staged construction versus detours. However, if project length is an important concern, the reduced time required for a full bridge closure may justify the additional cost of the detour.

As with any detour, there will be some inconvenience to motorists. However, the staged construction plan reduced the bridge to one lane of traffic with alternating traffic. Motorists would not be newly inconvenienced by a detour; they would be inconvenienced in a different way. Regardless of the choice of a detour, staging, or night work, some inconvenience to traffic will be caused because some form of road closure is necessary to properly complete the work.

CHAPTER 4. RAPID RELACEMENT OF EXPANSION JOINT WORKSHOP

4.1 Introduction

One important aspect to the replacement of expansion joints is the collaboration between the designers, constructors, and maintenance personnel working on each joint. Without the input of all involved parties, what may seem like a beneficial idea to one party may adversely affect another party. To meet this end, a workshop was held December 4, 2013 at the Iowa State University (ISU) Institute for Transportation (InTrans). Attending were representatives of three Midwest design consultants, three local Iowa contractors, the Iowa DOT Office of Bridges and Structures, the Iowa DOT Bridge Maintenance teams, the Iowa DOT Office of Construction, and the research team.

The workshop began with an introduction from Jim Nelson of the Iowa DOT Office of Bridges and Structures. Adam Miller (a Master's candidate at ISU) then followed with a brief overview of the research to that point.

4.2 Summary of Previous Research Tasks

4.2.1 Task 1 – Literature Review

Miller's presentation began with a short overview of the first research task, which was a thorough review of the existing literature. The literature review showed that, while there was a considerable amount of literature that addresses expansion joints, and particularly their durability, there was little information regarding their replacement.

Regarding other expansion joint literature, the review found that integral abutment joints are the preferred joint for new bridges (Chang and Lee 2001). For expansion distances greater than those allowed by integral abutment joints, strip seal expansion joints are being used increasingly throughout the US. In particular, many states are also replacing sliding plate joints and compression seal joints with strip seal joints. However, one research project discovered that a broad range of service lives were estimated by various states for strip seal joints. The service life of a strip seal expansion joint was estimated to be anywhere from 10 to 30 years (Guthrie et al. 2005). This information correlated with a University of Purdue study of expansion joints in Indiana that found strip seal joints were prone to early failure due to incorrect installation of the joint (Chang and Lee 2002).

4.2.2 Task 2 – Deterioration Patterns and Temporary Maintenance

The second research task involved the development of a visual record to document joint deterioration patterns as well as an explanation of the temporary maintenance activities that are conducted on expansion joints. The following information is the result of a day-long field investigation with Mark Carter, the Iowa DOT District 6 Bridge Crew Leader. (Further field

investigations will be conducted in the future as weather conditions and maintenance workloads allow.)

Sliding plate joints were the first addressed. The Iowa DOT no longer installs new sliding plate joints, but many are still in use in Iowa. It was found that rust was the most prominent problem with sliding plate joints. The water tightness of sliding plate joints was ignored because these joints were never designed to be watertight. Rusted joints have two primary undesirable consequences.

First, many existing sliding plate joints have had additional “raise plates” attached to match the driving surface of the joint to deck overlay surface. However, the existing joints were often in less than satisfactory condition. Often the “raise plates” were welded to a severely rusted existing plate. After enough rounds of traffic loading, the existing plate finally fatigues and fails. As a result, the new top plate comes loose from the bridge deck or back wall. Often, the lower plate of the joint is still intact, providing a riding surface for traffic. Thus, the joint still allows the passage of traffic and is effectively still functioning. This kind of joint failure only results in a low spot on the driving surface equal to the plate thickness, but the ride will not be smooth. The loose plate is usually removed and no further repairs are undertaken.

The second failure from rust occurs when the sliding plates rust and bond together. Eventually, this rust pack may cause the joints to become completely immobile. During periods of bridge deck contraction, these now immobile plates may pull free from the abutment back wall or, less commonly, the bridge deck itself.

Carter reported that, at times, he found large sections of the abutment had pulled free. Sliding plate joints that have pulled free require considerable effort to repair. The loose joint and any loose concrete must be removed. In older abutments, additional rebar may be added. This is however, often dependent on the age and design of the abutment and is done on a case-by-case basis if necessary. Due to time constraints, new joints are usually not installed; instead, a flat butt joint is constructed to allow for the expansion movement. This allows the deck to expand and contract as required, but does not create a smooth ride for traffic or prevent the passage of water.

Lastly, on a much less common basis is the simple fatigue failure of sliding plate expansion joints. While this failure is still a concern, the cause is often simply an undersized and under designed joint. The maintenance measures are similar to loose raise plates in that little is done. Carter explained that, early in his career, they would attempt to reattach sections of fractured plates, but welds used to attach the repair plates rarely proved to be durable and the practice was finally discontinued.

Compression seal and strip seal joints share many of the same deterioration concerns. The biggest problem for both joints is a buildup of incompressible material in the joint. Sand, salts, and other debris collect in the seal during the winter months. During summer bridge expansions, this material may prevent full joint movements and cause additional stresses at the joint anchorages. While the maintenance solution to this problem is simple, flush the joints clear of

debris at the end of every winter, this is not uniformly or regularly done. Joints are usually only cleaned when other work is being done on or near the joint making clearing the joint convenient.

Another common problem with both compression and strip seal joints is the spalling of edges of the concrete. If the spalls become severe enough, it may allow deterioration of the reinforcement in the end of the deck, and, thus, weakening of the joint. These spalls may also cause rust to build up behind the joint. This pack rust forces the joints forward and allows compression-seal armoring and strip-seal extrusions to be more easily caught by snowplows and more susceptible to damage from repeated traffic loadings. Spalls are repaired by typical concrete patching methods. Pack rust is a problem that cannot be easily dealt with and is often ignored until the steel components finally break free.

Unique to compression seals, sections of the steel armoring may break off under traffic loading. The quality of the concrete beneath the armoring often reveals inadequate consolidation of the concrete as the cause of these failures. The maintenance measure for this type of damage is to replace the failed section of steel armoring with concrete that matches the profile of the steel armoring. The armoring is in place to increase joint durability and does not actually aid in the expansion or waterproofing functions of these joints. Thus, while failing armoring is a sign of deterioration for the joint, it can still operate quite well with the temporary field repairs.

4.2.3 Task 3 – Jobsite Observations

The third research task consisted of observing current expansion joint replacement projects in an attempt to determine factors that affect the duration of a joint replacement. Several factors were noticed during these observations.

It was found that the single longest task in joint replacements was often the demolition of the existing concrete to be replaced. Among the demolition work, the largest driving factor was the existing rebar, particularly on jobs that required the replacement of the abutment and paving notch as well as the joint. The Iowa DOT generally requires existing rebar to remain intact to provide continuity between the existing footing and the new abutment and joint that will be placed (Jim Nelson, Personal Communication, Dec. 4, 2013). To remove the concrete from the existing rebar without causing significant damage, smaller demolition tools must be utilized, and often hand-held jackhammers. This greatly slows the demolition time.

The second main observation dealt with worker experience. There was a great deal of difference in the pace of a job whether the workers were experienced in joint replacements or inexperienced. This particularly related to the erection of formwork and placing of new rebar. In the researchers' prior experience, this is especially true in staged jobs. When formwork is erected and rebar placed in nearly the same fashion four times, the fourth time is always completed in less time than the first.

One unique jobsite observation was the use of hydrodemolition for the removal of an expansion joint. This particular job required only the removal of enough concrete to remove the joint and

place new rebar. Little to no concrete was removed from the abutment and the paving notch was left intact. There were several observed advantages and disadvantages to hydrodemolition. These pros and cons are listed below:

Pros:

- Hydrodemolition is fast and easy. After initial setup and preparations, little effort is required from the laborers.
- Existing reinforcing steel is left almost perfectly intact.

Cons:

- New equipment is costly to purchase.
- A significant amount of water is required with an equally significant amount of runoff containing small particles of removed concrete.
- While reinforcing is left intact, coatings will most certainly be removed from the bars.
- Jackhammer work will still be required to remove the joint entirely, although the amount of work is substantially reduced.

The last major jobsite observation consisted more of several discussions with the supervisors on the jobsites. One point that was made was that staging a project is expensive. The extra cost of traffic control and the extended length of time to complete the project are significant costs. As well, when joints are replaced in halves, the physical replacement takes longer than if it is replaced in one continuous section. One supervisor roughly estimated that, if a job was not staged, he could probably reduce his costs and job lengths each by approximately a third. However, complete closures of a bridge may create traffic problems in areas where detours are not readily available.

4.3 Pertinent Iowa DOT Design Standards and Design Considerations

Following Miller's overview, Nelson gave an overview of the pertinent design standards and an overview of the current practices of the Iowa DOT for the replacement of expansion joints. The presentation started with an overview of the types of expansion joints currently utilized by the Iowa DOT for newly constructed bridges.

The Iowa DOT currently utilizes integral abutments with up to 3 in. of CF joint at the paving notch. For Expansion of 4 to 5 in., a strip seal expansion joint is currently the preferred choice. Finger joints are utilized for expansion distances of up to 10 in., while modular expansion joints are recommended for movement up to 15 in. However, modular expansion joints are not commonly used by the Iowa DOT.

Integral abutments are the current method of choice for the Iowa DOT where bridge expansion is sufficiently small to be utilized. The Load and Resistance Factor Design (LRFD) Bridge Design Manual (www.iowadot.gov/bridge/manuallrfd.htm) limits pretensioned prestressed or precast prestressed concrete beam (PPCB) bridges to a length of approximately 575 ft for bridges without a skew and 425 ft at a 45-degree skew. Continuous welded plate girder (CWPG) bridges are

limited to an approximate length of 400 ft and 300 ft at a zero-degree skew and 45-degree skew, respectively.

Of particular interest in Nelson's presentation was a numerical breakdown of the expansion joints currently in use in Iowa. Currently, there are 1,065 bridges in the state utilizing some type of expansion joint. Just over half of these bridges are using existing strip seal expansion joints. Sliding plate joints are the next most commonly used joints on just fewer than 400 bridges. Since most of these sliding plate joints are near the end of, or past, their functional life, they are the most commonly replaced joint. With more than a third of Iowa's bridges still utilizing sliding plate joints, the replacement of these joints is a problem that will likely continue for several decades. Thus, efforts to improve the means and methods of replacing expansion joints will still be pertinent for the foreseeable future.

The presentation ended with an overview of several design concerns that must be taken into consideration when planning the replacement of an expansion joint. Narrow bridges are a significant difficulty. Lack of a good route detour causes many of these bridges to be candidates for a staged construction project. However, these narrow lanes can cause difficulties when staging a project. Lane widths less than 14 ft 6 in. require narrow width signing. As lane widths become narrower, it becomes an engineering judgment decision regarding the acceptable minimum lane width, as there is a predetermined standard. Temporary barrier rails separating moving traffic from construction crews exacerbate this problem. These barriers measure 1 ft 10.5 in. for precast concrete and 1 ft -1 5/8 in. for steel barrier rails.

A second design consideration is the splicing of existing reinforcing bars to new reinforcing bars. Lap splices are preferred, as it is easier to meet concrete cover requirements using them. However, with lap splices, the existing rebar must be left intact in largely good condition to be effective. Mechanical splices, on the other hand, require little more than a few inches of bar protruding from the existing concrete. Mechanical splices tend to be bulkier and require more concrete to meet cover requirements. Meeting these requirements can be difficult in a 7.5 in. thick bridge deck (Jim Nelson, Personal Communication, Dec. 4, 2013).

4.4 Breakout Groups, Idea Discussion, and Ranking

For the next part of the workshop, the participants divided into three separate groups with each specific discipline of design, construction, and maintenance evenly distributed among each group. This ensured that, during the discussions, every group would have design, construction, and maintenance represented. The groups were instructed to develop ideas relating to the overall improvement of expansion joints.

While the main focus of the meeting and research was on expediting the construction process, any and all ideas to improve expansion joints in general were considered. An idea to improve the lifespan may not directly help joints to be replaced more rapidly, for example, but replacing joints less often will still help alleviate future problems associated with bridge closures. Thus, any idea related to the improvement of expansion joints was considered.

A summary of the three separate group's discussions is included in Appendix A, as well as a tally of the final ideas discussed and a list of participants.

The underlying principal behind the discussion group results were as follows: if three separate groups of experts in their own fields came up with the same or similar solutions, those solutions are likely to be the most feasible solutions. At the very least, such a method gives the research team a way to determine which ideas are the most important to be investigated further within the course of this research study, and in future research projects.

After about 90 minutes, the groups were brought together as a large group for a working lunch to discuss as a large group what each smaller group had discussed. As previously suggested, several similar ideas had been discussed separately by each of the three groups. Similar ideas were then combined into common ideas, and these common ideas were all listed to be ranked by a voting process.

For the voting process, each member present was given 10 separate tags to be placed next to the ideas they believed were the most pertinent to undergo further actions. Twenty-seven total ideas were considered during the voting process. The complete list is included in Appendix B. The top 10 ideas (by number of votes) are expanded upon in the next subsection.

4.5 Workshop Results

4.5.1 Assess Existing Joint Behavior

Existing expansion joints are selected largely based on the expansion distance required by a bridge. Tests should be conducted to measure the actual joint expansion distance, which can be compared to the theoretical joint expansion distance. This should be particularly noted with respect to the age of a bridge. The pertinent question to ask is if the required expansion for the bridge reduces with age so that, when joints need to be replaced, they may be replaced with a more easily maintained joint that allows less movement (e.g., a finger joint to a strip seal or a strip seal to a semi-integral abutment).

4.5.2 Develop Standard Detail for Precast Joint, Paving Notch, and Approach

Discussions with the contractors present during the workshop revealed that concrete cure time may consume as much if not more time than concrete removal and that this time spent waiting for concrete to cure could be reduced with the use of precast members. Time savings could be increased by an even larger amount if existing rebar in the concrete that is to be removed is not required to be maintained as protruding rebar to facilitate lap splicing.

4.5.3 Increase Use of Semi-Integral Abutments

During discussions with the contractor representatives who were present, it was stated that integral abutment and semi-integral abutment expansion joints are the favored joints among contractors. These are the easiest and quickest joints to erect, as the sections are more or less just rectangles with a paving notch. The standardization of details makes these joints faster and easier to construct than stub-type abutments.

4.5.4 Eliminate Strip Seal Upturn at Gutter and Develop Drainage System

The main cause of deterioration in strip seal expansion joints is from the accumulation of debris in the neoprene seal. Currently in Iowa, strip seal joints are designed to prevent the flow of water through the joint. Sand, deicing salts, and other debris are collected in the joint during the winter months. This debris can cause splits under traffic loading, or prevent full expansion during summer months.

The workshop participants concluded an alternate system should be developed that reroutes water through a drainage system depositing contaminated water away from important structural members while still maintaining a watertight membrane at the joint. The flow of water would also prevent debris accumulation by flushing debris from the joints.

4.5.5 Develop a Proactive Maintenance Program

Currently, joint components are replaced when they fail. Most commonly, this means failure of neoprene glands in strip seals and compression seal glands. The wait time between the discovery of these failures, programming, bidding, and finally replacement can mean a significant amount of time that a joint is functioning but not watertight.

Carter suggested that, in his experience, most strip seal glands fail at about 15 to 20 years while compression seal glands fail most commonly after 10 years. Thus, glands should be replaced proactively to prevent failure instead of waiting until failure has already occurred.

4.5.6 Evaluate the Use of Dowel Bars and Fast-Curing Concrete

Demolition and cure times are two of the longest tasks during a joint replacement. In general, the Iowa DOT prefers to maintain the existing vertical bars in stub abutments to allow the usage of lap splices. This requires that the concrete be removed from the bars while the bars remain in largely good condition. Smaller demolition tools must then be utilized to remove the concrete, slowing the overall pace of the job. Allowing the complete removal of the vertical bars will allow removal times to be significantly shorter, or about one work day in the researcher's prior experience, instead of the several days that it now currently takes. The use of new reinforcing steel doweled and grouted into the old footing will add additional rebar placement time, but this added time should be a fraction of the time saved in removal.

4.5.7 Develop a Mechanical Attachment for Future Joint Replacements

Current expansion joints are generally cast integrally with the concrete bridge deck. When joint replacements are necessary, this requires that concrete be demolished, new rebar placed, formwork erected, and new concrete placed. A retrofitted mechanical attachment would alleviate future problems. Similar to replaceable parts in a mechanical system (car, machinery, etc.), these joints would be designed to be easily replaced.

4.5.8 Evaluate Concrete Mixes and Better Specify Proper Use of High Early-Strength Concrete

During the workshop discussions, the contractor representatives noted that concrete cure time may extend joint replacement schedules almost as much as concrete removal time. Concrete mixes that reach usable concrete strengths in as little as 24 hours or less are currently available. However, in rural areas where such mixes are not used as regularly, necessary maturity data may not be available. In addition, guidelines should be developed to better specify when certain mixes are truly beneficial. An 8-hour concrete mix would be beneficial on an overnight project, but would have no benefit over a 24-hour concrete mix on an extended closure.

4.5.9 Determine Allowed Movement for Different Concrete Mixes

Concrete mixes of cement, aggregate, and polymer have been used previously to serve the same functions as an expansion joint gland to accommodate small movements in bridge decks. Other mixes of asphalt binder and aggregates are available that have been proven useful in accommodating expansion. However, the Iowa DOT has not done an in-depth study for the amount of expansion that could be allowed for the many different concrete mixes that currently exist. Some polymer and asphalt concretes may allow sufficient elastic movement for short bridges to allow the elimination of expansion joints altogether. In particular, the Michigan DOT has been experimenting with the use of engineered cementitious composite link slabs in bridge deck rehab as opposed to traditional expansion joints.

4.5.10 Develop Emergency Procedures for Evaluating Necessary Quality of Repair

During prior research tasks, trips, and discussions with Carter, it was discussed that, at a handful of times during the year, emergency repairs were necessary on expansion joints. The repairs often included the removal of significant portions of the existing back wall and large sections, if not the entirety, of the expansion joint. Repairs were often completed in as little as eight hours to restore use of the bridge to traffic.

Both the Iowa DOT maintenance personnel and the contractors at the workshop noted that the concrete removal during these repairs already constituted about half of the work required in a normal joint replacement. Both also seemed to agree that, with a longer closure time (possibly as little as 2 to 3 days) and a few other changes, these temporary repair efforts could easily be expanded into complete joint replacement projects.

CHAPTER 5. CONCLUSION AND CONTINUING RESEARCH EFFORTS

5.1 Conclusion

This report is intended as an interim report to update the Iowa DOT on the current progress of this research project. To date, the research team has worked to document the current means of repairing expansion joints by in-house maintenance staff as well as to document the deterioration signs noticed by the field staff that maintenance will soon be required of a specific joint type.

Concurrently, the research team documented the current means and methods of replacing failed bridge deck expansion joints.

Lastly, a workshop was held between the research team, Iowa DOT personnel, and outside consultants to develop ideas relating to the overall improvement of expansion joints. The focus of the workshop was intended to be on expediting the construction process, but no limitation was placed on the ideas presented, as long as they met the overall goal of improving bridge deck expansion joints.

5.2 Continuing Research Efforts

There are several upcoming tasks to be completed by the research team. The initial proposal tasks of documenting the in-house means and methods of repairing expansion joints will be expanded to include the input of the bridge crew leader of a western Iowa district to compare the maintenance measures on each side of the state. Further bridge crew leaders will be contacted for information if deemed necessary or if there is a large variance in maintenance and repair measures discovered throughout the state. Furthermore, the research team has amended to the initial proposal to include tasks developed after the initial expansion joint workshop was held. These tasks are outlined below.

5.2.1 Precast Joint/Mechanical Joint Workshop

The research team will hold a workshop similar to the previous expansion joint workshop. This workshop will focus specifically on developing a method to either prefabricate or mechanically attach a replacement expansion joint as opposed to an integrally cast joint. Following the workshop, ideas will be analyzed for cost and feasibility. If warranted ideas will be further investigated under a following research proposal.

5.2.2 Evaluate the Different Construction Methods Used for Joint Replacement

Several differing methods were discussed during the first expansion joint workshop. A selection of Iowa contractors will be interviewed to develop a realistic project schedule for the differing methods. Cost, and life cycles issues, will then be analyzed.

5.2.3 Evaluate Concrete Mixes and Specifications for Use

During the workshop, it was discussed that concrete cure times are second only to demolition time for task length. There are numerous existing types of concrete including Portland cement concrete and high early strength concrete, and several different proprietary elastomeric concretes. Cure time and final strengths of these concretes vary significantly. Guidelines will be proposed to specify when some concrete mixes should be used instead of a typical 28-day 4ksi concrete mix.

5.2.4 Develop Procedures for Determining Quality of Emergency Repairs

Previous tasks discovered occasional major joint failures that require a significant emergency repair. Often, these repairs require the removal and replacement of a substantial amount of concrete. To quickly open these bridges to traffic, these repairs typically leave the expansion joint open allowing the necessary expansion distance for the bridge deck, but not preventing the passage of water or providing a smooth ride for traffic. The research team will develop procedures to determine the quality of emergency repair to complete, while balancing the length of closure to complete the repair with the quality of the repair to be completed.

REFERENCES

- ASTM Standard D 4580. 2012. "Standard Practice for Measuring Delaminations in Concrete Bridge Decks by Sounding." ASTM International, West Conshohocken, PA.
- Chang, L. M., and Y. Lee. 2001. *Evaluation and Policy for Bridge Deck Expansion Joints*. Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, IN.
- Chang, L., and Y. Lee. 2002. Evaluation of Performance of Bridge Deck Expansion Joints. *Journal of Performance of Constructed Facilities*, 16(1), 3-9.
[dx.doi.org/10.1061/\(ASCE\)0887-3828\(2002\)16:1\(3\)](https://doi.org/10.1061/(ASCE)0887-3828(2002)16:1(3))
- Dexter, R. J., Connor, R. J., and Kaczinski, M. R. 1997. *NCHRP Report 402 Fatigue Design of Modular Bridge Joint Systems*. Transportation Research Board, National Research Council, Washington DC.
- D.S. Brown Company. 2006. Steelflex Modular Expansion Joint System – D240-PV-S. Retrieved from www.dsbrown.com/Bridges/ExpansionJointSystems/Modular.aspx
- D.S. Brown Company. 2012. Steelflex Strip Seal Expansion Joint – SSE2M. Retrieved from www.dsbrown.com/Bridges/ExpansionJointSystems/Steelflex.aspx
- Guthrie, W. S., Yuen, L. H., Ross, L. A. 2005. *Performance of Concrete Bridge Deck Joints*. Brigham Young University for Utah Department of Transportation Salt Lake City, UT.
- Iowa Department of Transportation. 2013. April 16, 2013 Bid Tabulations. Retrieved from www.iowadot.gov/contracts/lettings/130416_BidTabs.pdf
- R.J. Watson, Inc. *Silicoflex Joint Sealing System*. www.rjwatson.com/wp-content/uploads/silicoflex-brochure-may.pdf
- Watson Bowman Acme Corporation. 2010. Wabo Compression Seal – WA-500. Retrieved from wbacorp.com/products/bridge-highway/joint-seals/wabo-compressionseal-bridge-series/

APPENDIX A. WORKSHOP PARTICIPANTS, OVERVIEW, AND RESULTS

Workshop Participants

Note: The participants were split into three roughly equal groups each containing, to the best of our abilities, an equal number of specialized participants in each group.

Group 1

1	Wayne Sunday	Iowa DOT	Construction
2	Matt Johnson	TranSystems	Consultant Design
3	Andy Stone	United Contractors	Contractor
4	Jim Nelson	Iowa DOT	Design
5	Mark Harle	Iowa DOT	Design
6	Mark Carter	Iowa DOT	Maintenance
7	Linda Narigon	Iowa DOT	Research Administration
8	Adam Miller	ISU	Research Team

Group 2

1	Scott Nixon	Iowa DOT	Construction
2	Stan Stallsmith	WHKS	Consultant Design
3	Dan Cramer	Cramer and Associates	Contractor
4	Dean Bierwagen	Iowa DOT	Design
5	Ahmad Abu- Hawash	Iowa DOT	Design
6	Justin Sencer	Iowa DOT	Maintenance
7	Justin Dahlberg	ISU	Research Team

Group 3

1	Steve Kunz	Shuck-Britson	Consultant Design
2	Roger Anderson	Cunningham-Reis	Contractor
3	Gary Novey	Iowa DOT	Design
4	George Kotlers	Iowa DOT	Design
5	Gordy Port	Iowa DOT	Maintenance
6	Greg Mize	Iowa DOT	Maintenance
7	Chuck Jahren	ISU	Research Team

Rapid Bridge Deck Joint Repair Investigation Workshop Agenda
Iowa State Institute of Transportation
12/4/2013

Welcome and Introduction. Jim (15 minutes)

Research Overview. Adam and Chuck

Lit Review Brief (5 to 10 minutes)

Joint types and deterioration patterns (30 minutes)

Temporary joint maintenance measures (10 minutes)

Joint replacement construction observation (30 minutes)

Joint design practices and details. Jim (20 minutes)

Break out session tasks and goals. Chuck (10 minutes)

3 Pre-assigned breakout groups (45 minutes)

Lunch. 3 Group leaders report on the discussion and ideas (45 minutes. 1 hour)

Group discussion of the ideas, voting and ranking. Jim (30 minutes)

Conclusion and wrap up, what's next. Chuck (10 minutes)

Workshop Results Breakdown

Future Projects

Assess Existing Joint Behavior. Proposed

1. Eliminate Strip Seal Upturn at Gutter and Develop Drainage System – Proposal requested from InTrans

Further Investigations under this Project

1. Develop Standard Detail for Precast Joint, Paving Notch, and Approach
2. Evaluate the Removal of Embedded Rebar And Use of Dowel Bars
3. Develop a Mechanical Attachment for Future Joint Replacements
4. Evaluate Concrete mixes and Specify Proper use of High Early Strength Concrete
5. Determine Allowed Movement for Different Concrete Mixes
6. Develop Emergency Procedures for Evaluating Necessary Quality of Repair

Refer to DOT

1. Increase use of Semi-Integral Abutments

On Hold for Future Consideration

1. Develop a Proactive Maintenance Program

Workshop Final Ideas Listed by Final Tally

Rank	Idea #	Final Tally	Explanation
1	1	28	Assess joint behavior, monitor/test expansion, measure actual joint expansion distance vs. theoretical expansion distance, possibly eliminate joint or move to longer length for integral or semi-integral abutments
2	8	27	Create standard detail for a precast/prefab joint as well as approach and paving notch
3	13	24	Increase use of semi-integral abutments.
4	19	23	Stop strip seal at gutter and develop and alternate drainage system/alternate joint configuration.
5	5	21	Schedule routine maintenance and gland replacements. Mark Carter suggests automatically replacing strip seal glands at 15-20 years and compression seal glands at 10 years.
6	4	18	Evaluate using a full-depth sawcut and complete removal of the joint. Combine with evaluating use of fast curing concrete and use of dowel bars
7	11	16	Create a mechanical attachment for current joint replacements to accommodate future joint replacements.
8	16	15	Evaluate different concrete mixes and determine when it would be proper to use faster curing mixes.
9	9	13	Determine allowed movement for various concrete mixes. For example polymer concretes allow some small movements without an expansion joint
10	27	13	Emergency repair procedures for evaluating if a more permanent repair is warranted over a temporary repair.
11	7	12	Include user costs in construction estimate. Increase incentive dollars for accelerated projects. Also create realistic evaluation of how fast joints need to be replaced.
12	18	10	More carefully consider the required number of concrete pours.
13	25	10	Prequalify rapid replacement contractors.
14	26	9	Design steel plate bridges to allow temporary traffic usage over joint construction areas during peak traffic hours.
15	3	7	Ensure proper installation of expansion joints, ensure proper joint spacing vs. ambient temperature, solve extrusion fabrication issues
16	10	7	Evaluate emerging new technologies for use in expansion joints replacements. E.g. FRP dowel bars, UHPC, impregnated foam glands, bonded glands, shape memory Mat'l.
17	17	6	Study removal tools, productivity rates, and quality consequences.
18	21	6	Provide more 3D views of complicated concrete areas.
19	2	5	Contract regular cleaning of expansion joints
20	6	3	Widen bridges to accommodate traffic on new lanes while replacing joint on old lanes
21	22	3	Use empirical deck design at expansion joints
22	15	2	Increase use of hydrodemolition.
23	20	2	Improve design and durability of neoprene troughs.
24	24	2	Cantilever finger joint to dump water away from piers.
25	12	1	Allow contractors more freedom in choosing the type of replacement expansion joint.
26	14	1	Design replacement joint for partial deck embedment. This allows for more shallow removal and less demolition.
27	23	1	Double stack strip seal to prevent leakage if one seal fails.

APPENDIX B. WORKSHOP GROUP DISCUSSION NOTES

Bridge Deck Expansion Joint (BDEJ) Group 1 Discussion Notes

Design

- Tied approach, sleeper slab. Move joint off bridge
 - If joints leak into subgrade layer it is a significantly smaller concern than deicing chemicals leaking onto beam ends.
- Configuration of Strip Seal at edge of deck. Run joint straight through the curb allowing water and salts to drain out end of joint.
 - MnDOT may already use such a detail.
- Orientation of the Strip Seal gland
 - Invert the gland (looking like an inverted V) to help push debris out of gland during summer expansion times.
- For repairs welding a section of extrusion in between two existing sections of extrusion does not work well. However, extending a repair section from the damaged area to the edge of deck does work.
 - The welded section tends to expand differently than the original sections causing the welded repair section to buckle. If the section extends to the edge of deck one end is not confined.
- If extrusion durability is a problem use alternative materials to steel (e.g. carbon fiber) for extrusions.
- Curb plate recess is not deep enough. With existing construction tolerances snow plows are catching the edge of the plate.
- Expand the use of jointless bridges.
 - Contractors prefer integral abutments because the entire end section is more or less just a large rectangle.
 - Tennessee currently uses the Kingsport? Bridge that is almost 3,000 ft long. The only existing expansion joints are modular joints on either end.
- Design joints for replacement.
 - Make initial construction details with provisions for when the joint will need replaced.

- Doweled reinforcing bars vs. bonded bars.
- Use special materials e.g. Epoxy concrete with quick cure times or UHPC.
- Use troughs under sliding plates
 - The only serious problem with sliding plate joints stems from joint leakage.
- Use an empirical deck design at joints to eliminate some reinforcing.
 - Less reinforcing allows for easier and faster demolition.
- Use a double stacked strip seal.
- Modular joints vs. Finger joints
 - Finger joints are preferred in urban areas due to noise.
 - Modular joint more durable than finger joints if properly maintained.
 - Maintenance on Modular Joints is lacking in training.
- Neoprene trough details not robust enough.
- Cantilever finger joint if you can dump water.

Construction

- Integral abutments are the preferred design
 - Smoothest joint and easiest to construct
- Fabrication issues
 - Welds at joint anchorages are failing
 - Manufacturing of rubber for seals is slipping. Glands are arriving with splits and showing early failure compared to older seals.
- Construction of concrete around turn ups problematic for strip seals.
- Materials
 - Quick curing concrete mixes are common and have significant maturity data in large urban areas. Quick curing mixes can be more difficult to come by in less populated areas.

- Field segments of extrusions. Some splices are occurring under traffic wheel paths.
 - Revise standard notes on where splices are permitted in joints.
- Prequalify rapid joint replacement contractors
 - The experience required for a three month job and a three day job differ significantly.
- Steel plating over joint work to allow traffic to use all lanes during peak traffic hours.
- More scrutiny of duration of closures and staging
 - Is staging really necessary or is a detour possible.
 - Detours tend to allow better quality work to be done sooner at a lower cost.
 - Motorists may be inconvenienced.
 - Shut downs for 2-3 days instead of 8-10 hours may produce a better quality more durable joint.

Maintenance

- Use rapid set deck patch mix for repairs
 - 12-15 min. working time with rapid cure times.
- Strip seal patch is a tool that has its place but is not a cure-all.
- Train staff to properly maintain modular joints
- Replace modular joints components as they fail.
 - With proper maintenance modular joints may outlast most other joints.
- Prefab replacement details
- Full depth saw cut and dowel
 - A significant amount of demolition time is spent removing concrete while keeping bars straight.
- Automatically replace strip seal glands at 15-20 years
 - Begin a proactive maintenance program instead of waiting for glands to fail.

- Replace compression seals at 10 yrs.
 - Existing stop bars may not accommodate newer compression seals.
- Regularly clean glands
 - Again have a proactive maintenance program.
- Extension of strip seal through curb to drain seals
 - Wind issues – where does the liquid go from there?
- Extend closures of partial emergency repairs
 - Extend closures 2-3 days from 8 hours and install strip seal extrusions.
 - Result will be a new watertight joint instead of a makeshift repair that may slowly cause other problems until a proper replacement is done.

BDEJ Group 2 Discussion Notes

- Assess Joint Behavior – Monitor/test to determine if joint could be eliminated.
- Contract cleaning of expansion joints
- Ensure proper installation of expansion joints
- Full depth sawcut and complete removal of embedded rebar
 - Effect on decks using dowel bars?
- Routine Schedule maintenance
- Widening bridges to accommodate joints replacement
 - In areas where bridge widening is already expected to occur
- Include user costs in estimate/increase incentive \$ for accelerated jobs
- Precast/Prefab joint
 - Create a standard detail for this
- Different concrete mixes allow a different amount of movement
- Evaluate/establish use of emerging technologies

- Mechanical attachment of expansion joints
 - Accommodate future replacement of joints
- Joint Selection/Contractor Option
- Increase use of Semi-Integral Abutments
- Design replacement joint for partial deck embedment
- Require hydrodemolition?

BDEJ Group 3 Discussion Notes

- Encourage detours whenever possible
- Consider using maintenance concrete mix that will set up faster
 - Use maturity method to determine concrete strength. Get ready mix plants and suppliers to help.
- Precast elements together
- Hydrodemolition
 - Mobilization is expensive
 - Will work better without staging
 - Solve water collection/supply issues
- Solve concerns of removal of concrete from prestressed beams
- Utilize dowel bars more so rebar can be cut
 - Solve concern about dowling into a 7.5" deck
 - More stable for dowling if working over a diaphragm
 - Maintaining rebar is a bigger problem at the backwall than the horizontal bars on the deck side.
- Document productivity of concrete chipping removal with various removal methods.
- Determine how close constructed joint expansion/contraction distance is to the theoretical designed difference.

- Adjustment can be made at backwall.
- Glands can tear in the winter
- Determine how quickly bridges react to temperature changes. Where does the temperature apply.
- Number of pours and cure time may be more important than demo time.
- Can several pours be combined into a single pour
 - Backwall, Deck, Curb, Barrier rail, approach panel etc.
- Stop Strip Seal at gutter line and collect the water e.g. with drainage pipe.
- Address problems of maintaining “diapers” They tear at attachment eyelets. E.g. Vets bridge in Sioux City
- Turn up @ curblines is problematic
- Contract gland replacement
 - Resolve responsibility for sealing if the extrusion is in bad condition.
 - Revise water test spec requirements
- Consider providing 3d isometric views of how to form complicated pieces of concrete
 - Particularly where a skew is involved
- Can glands be inserted into bridge rail and curb areas without special formwork to make working room?
- Complete gland replacements in cold weather when joints are open
- Use light torch to get “glue” out
- Reformulate lubricant adhesive for quicker cleanup during removal of gland
- Wash bridges and joints at regular intervals.
- Mitigate traffic control
- Precasting – how can it be done?
 - How would you precast decks?
 - Precast paving notch might be easier

- Joint setup time is significant?
- Precast approach, top of backwall and extrusion together
- More projects are just top of backwall to paving notch
- Contractor could precast at site
- Consider hotter mixes on closure joints, back into the approach panel.
 - Dowel with FRP bars?
- Ensure durability of new concrete mixes
- 24 hour cure concrete mix would be very helpful. However, in most cases there would not be much benefit to a cure time less than 24 hours.
- Pour curb and Rail at same time.