Laboratory Investigation of Bridge Strip Seal Joint Termination Details

BRIDGE ENGINEERING CENTER

Final Report
February 2016

IOWA STATE UNIVERSITY
Institute for Transportation

Sponsored by
Federal Highway Administration
Iowa Department of Transportation
(InTrans Project 14-302)

About the Bridge Engineering Center

The mission of the Bridge Engineering Center (BEC) at Iowa State University is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
InTrans Project 14-502		

4. Title and Subtitle	5. Report Date
Laboratory Investigation of Bridge Strip Seal Joint Termination Details	Februrary 2016
	6. Performing Organization Code
7. Author(s)	**8. Performing Organization Report No.**
Travis Hosteng and Brent Phares	InTrans Project 14-502
9. Performing Organization Name and Address	**10. Work Unit No. (TRAIS)**
Bridge Engineering Center Iowa State University 2711 South Loop Drive, Suite 4700 Ames, IA 50010-8664	**11. Contract or Grant No.**
12. Sponsoring Organization Name and Address	**13. Type of Report and Period Covered**
Iowa Department of Transportation 800 Lincoln Way Ames, IA 50010 Federal Highway Administration 1200 New Jersey Avenue SE Washington, DC 20590	Final Report **14. Sponsoring Agency Code** SPR RB08-014

15. Supplementary Notes

Visit www.intrans.iastate.edu for color pdfs of this and other research reports.

16. Abstract

Bridge expansion joints, if not properly designed, constructed, and maintained, often lead to the deterioration of critical substructure elements. Strip seal expansion joints consisting of a steel extrusion and neoprene gland are one type of expansion joint and are commonly used by the Iowa Department of Transportation (DOT).

Strip seal expansion joints are susceptible to tears and pull outs that allow water, chlorides, and debris to infiltrate the joint, and subsequently the bearings below. One area of the strip seal that is particularly problematic is where it terminates at the interface between the deck and the barrier rail. The Iowa DOT has noted that the initial construction quality of the current strip seal termination detail is not satisfactory, nor ideal, and a need exists for re-evaluation and possibly re-design of this detail.

Desirable qualities of a strip seal termination detail provide a seal that is simple and fast to construct, facilitate quick gland removal and installation, and provide a reliable, durable barrier to prevent chloride-contaminated water from reaching the substructure.

To meet the objectives of this research project, several strip seal termination details were evaluated in the laboratory. Alternate termination details may not only function better than the current Iowa DOT standard, but are also less complicated to construct, facilitating better quality control. However, uncertainties still exist regarding the long-term effects of using straight-through details, with or without the dogleg, that could not be answered in the laboratory in the short time frame of the research project.

17. Key Words	18. Distribution Statement
barrier rail construction—bridge expansion joints—bridge joint details—bridge maintenance—gland installation—strip seal termination—substructure protection	No restrictions.

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified.	Unclassified.	67	NA

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

LABORATORY INVESTIGATION OF BRIDGE STRIP SEAL JOINT TERMINATION DETAILS

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Sponsored by
the Iowa Department of Transportation and
the Federal Highway Administration

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
(InTrans Project 14-502)

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ACKNOWLEDGMENTS

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

The engineers at the Iowa DOT Office of Bridges and Structures also deserve recognition for their technical advice and support on this project. In particular the authors would like the thank Norm McDonald, Ahmad Abu-Hawash, Gordon Port, Jim Nelson, Wayne Sunday and Gary Novey for their creativity and technical advice.

EXECUTIVE SUMMARY

Problem Statement

Engineers with the Iowa Department of Transportation (DOT) Office of Bridges and Structures noticed that the construction quality of the strip seal termination detail on many of their bridges, and particularly on skewed bridges, is not satisfactory, nor ideal, and that a need exists for re-evaluation and possibly re-design of this detail.

Background

In Iowa's climate, bridges expand and contract about an inch for every 100 feet of bridge length from the coldest day in winter to the hottest day in summer. One method of accommodating these thermal movements is through the use of expansion joints located on the superstructure, typically above either the abutments and/or the piers.

Expansion joints are often outfitted with a flexible watertight seal that protects the substructure from water, chlorides, and debris infiltration from the bridge deck. The strip seal is a popular expansion joint device, commonly used in Iowa and many other states, that provides a watertight seal capable of accommodating 4 to 5 inches of movement.

In Iowa, strip seals are currently the preferred expansion joint device for thermal movements up to 4 inches. This is due to the strip seal's relatively good durability and performance when compared to other types of expansion joint devices.

The strip seal system is comprised of steel extrusions that are cast in the concrete deck and a neoprene gland that fits into cavities in the extrusion These expansion joint seals are susceptible to tears and pull outs that allow water, chlorides, and debris to infiltrate the joint, and subsequently the bearings below.

The debris present in the gland when the bridge starts to expand in the summer, due to increasing temperatures, causes tearing of the gland and allows chloride-contaminated runoff to reach the substructure. One area of the strip seal that is particularly problematic is where it terminates at the interface between the deck and the barrier rail.

Strip seal termination details vary from state to state. In Iowa, strip seals run transverse to the bridge deck and terminate by turning up and into the barrier rail in a two-step turn. The turn-up prevents water from flowing over top of the strip seal, where it could then reach and cause deterioration to substructure elements below.

Many states have strip seals that turn up in one step, some in two steps, at different angles, and some that run flat through the barrier rail and terminate at the exterior edge of the deck. Other states have strip seals that take horizontal "dogleg" bends in the deck before reaching the barrier rail. The many details and variations that exist have little to no written documentation on construction quality, joint performance, or maintenance requirements from either a laboratory or a field perspective.

Field inspections have found that the poor performance of the current Iowa DOT termination detail often stems from the fact that the blockout region around the strip seal turn-up is not fabricated with the best construction methods and/or quality control practices. Often, a larger than necessary void in the barrier rail is left around and behind the strip seal turn-up during barrier rail construction, and the void is later filled by hand packing concrete into it.

Research Objectives

Noting this construction deficiency with the blockout region early on in the research project, the research team sought to re-evaluate the current termination detail as well as test alternate termination details.

Research Description

Constructability, gland installation, and water-tightness were the three criteria established to evaluate and compare the details investigated: current turn-up termination detail (Iowa DOT standard), straight-through termination detail, dogleg termination detail, and bentonite option detail.

Given that the Iowa DOT experiences the most severe problems with the strip seal termination detail on skewed bridges, all laboratory specimens were constructed at a 30 degree skew. This ensured that recommendations for new or improved details were tested under the most critical circumstances.

The construction procedure for each termination detail was evaluated and, once the barrier rail was installed on each specimen, the process of installing and removing the gland was evaluated. This ensured that the glands could be installed and reinstalled without interference from the completed barrier rails, and accounted for the fact that contractors sometimes install the glands before completion of the barrier rails.

Ponding tests were then conducted on each specimen, given it is standard to inspect and evaluate that the joint is sufficiently watertight for all strip seal joints in the field.

Key Findings, Results, and Conclusions

The current turn-up termination detail was the most challenging specimen to construct in the laboratory. The detail was difficult to visualize and understand from a set of two-dimensional plans, which added difficulty and confusion to the construction. The research team gained a better understanding of the detail from viewing a three-dimensional (3D) model and photos of a strip seal termination provided by the Iowa DOT.

Forming the barrier rail and blockout area around the turn-up portion of the strip seal metal extrusion was difficult because of the complex geometries present; however, proper construction was attained through a basic construction procedure that eliminated the necessity for hand packing of concrete by contractors later. The solution was to use foam to form the blockout around the turn-up.

For evaluation purposes, two different foams were utilized: blue foam insulation board and a spray foam product. In both cases, after the formwork or foam was removed, the resulting finish was desirable and the blockout area allowed for full installation of the gland. Furthermore, through trial and error, the research team found that the blockout area of the current Iowa detail can be modified so that the blockout is only as wide as the steel extrusions of the strip seal. In fact, the research team found that the smaller blockout area improved installation of the gland because the new surface provided better tool leverages.

The deck pour encapsulation method was an alternative construction method that the researchers investigated for the current turn-up detail. This method of construction involves forming and casting part of the concrete barrier rail and blockout region around the strip seal termination (turn-up) simultaneously with the deck pour. The advantage of the deck pour encapsulation method is that, once the strip seal turn-up is encapsulated in concrete with the deck pour, the barrier rail can be cast in one seamless step, whether cast in place or slip formed.

The straight-through and dogleg termination details, which both pass through the entire width of the barrier rail and terminate at the exterior edge of the bridge deck, were investigated as termination detail alternatives. These details are similar in that they involve simple geometries between the strip seal, deck, and barrier rail, and are substantially easier to construct than the turn-up detail, regardless of the construction technique (i.e., using blockout techniques or the encapsulation method).

During investigation and design of these details, concerns were expressed related to two key areas: the amount of working room between the barrier rails once fully cast to facilitate installation/repair of the strip seal gland and control of runoff water passing between the barrier rails and off the end of the gland.

The Iowa DOT currently allows contractors to choose between two strip seal manufacturers, D.S. Brown and Watson Bowman Acme, for installation on a new bridge, so those strip seals were the ones evaluated.

For the D.S. Brown strip seal, the gland installation between the barrier rails proved to be simple, taking a total of 10 minutes, and was achieved using a basic pry bar. Both the dogleg and straight-through of the D.S. Brown specimens passed all ponding tests.

The Watson Bowman Acme strip seal was difficult to install between barrier rails, taking the research team approximately 80 minutes to complete. The installation process was cumbersome because of the need for additional working room for the custom installation tool provided by the manufacturer to properly install the gland.

In the laboratory, the Watson Bowman strip seal straight-through detail passed the ponding test, while the Watson Bowman dogleg detail did not. The dogleg detail did not pass any of the ponding tests performed after multiple attempts to install the gland properly. The dogleg bend in the metal extrusion was too sharp for the gland to be properly installed into the extrusion, which caused water to leak through the gland/extrusion/joint.

With a straight-through strip seal joint, the issue arises of water runoff exiting the side of the bridge deck from the strip seal. The main concern here is that chloride-contaminated water runoff from the bridge deck, if not properly channeled away, would trickle down to the substructure and bearings. However, Kansas and Missouri currently use this detail for their strip seal termination and utilize basic water drainage techniques to direct runoff safely off the bridge deck and away from the bridge substructure underneath.

Ultimately, laboratory results indicate that the straight-through details, with or without the dogleg, provide exceptional alternatives to the turn-up termination detail. The straight-through option is easily detailed on plans with no loss of clarity, the detail is construction-friendly, and it results in a high-quality, highly effective end product.

The other alternative detail investigated involved a straight-through or dogleg termination design placing granular bentonite in the void between the barrier rails with blocking plates attached to both the front and back faces of the barrier rails. When the bentonite is exposed to moisture or runoff from a rain event, the expansiveness of the bentonite clay blocks the void between the barrier rails and prevents water from draining from the bridge deck.

The bentonite clay proved to work well at creating a watertight seal to the termination area and passed multiple ponding tests. However, repeated ponding tests caused some of the bentonite clay to fall out of containment within the barrier rail void and onto the deck.

This is a potential maintenance concern for two reasons: the amount of bentonite in the void may need to be added to continually and any bentonite that escapes under the blocking plate onto the concrete surface results in a slippery surface. Measures can be taken for better containment of the bentonite; however, it is quite difficult to ensure the bentonite would never escape containment.

Recommendations

- If a blockout is to be utilized around the current strip seal termination turn-up, forming the blockout with blue foam board is both efficient and results in a quality product. If spray foam is utilized, the face of the metal extrusion should be scraped and scrubbed clean of all spray foam residue prior to casting the barrier rail.

- Modifying the current Iowa termination detail so that the blockout is only as wide as the steel extrusions of the strip seal simplifies the detail on paper and in construction, while maintaining enough working room to install and remove the gland from the strip seal termination. Redrawing the blockout area and/or noting this on the plans defines the blockout geometry in a more quantifiable way, which may clear up confusion and lead to a more consistent and quality end product.

- The deck pour encapsulation method is a viable alternative for the construction of the current Iowa turn-up termination detail after accounting for the head pressure from the encapsulation block on the adjacent deck concrete during construction. Once this issue is addressed, the construction technique produces a quality product that reduces construction difficulties.

- To ensure the strip seal gland's full lifetime, cleaning and removal of debris should be performed periodically. The most important time for the cleaning and removal of debris is after winter, when the gland is in an open state and is filled with larger debris.

- If straight-through details, with or without the dogleg, are adopted, chloride-contaminated water runoff from the bridge deck should be properly channeled away so that it does not trickle down to the substructure and bearings. Gutters, tubing, corrugated plastic pipe, drip edges, etc. would need to be investigated to possibly direct runoff safely off the bridge deck and away from the bridge substructure underneath.

- If the straight-through or dogleg termination design placing granular bentonite in the void is adopted, use on areas near a sidewalk or with pedestrian/bicycle traffic may need to be avoided.

Implementation Benefits and Readiness

Proper design, construction, and maintenance of bridge expansion joints are important in helping to prevent the deterioration of critical substructure elements. Desirable qualities of a strip seal termination detail provide a seal that is simple and fast to construct, facilitate quick gland removal and installation, and provide a reliable, durable barrier to prevent chloride-contaminated water from reaching the substructure.

Alternate termination details may not only function better than the current Iowa DOT standard, but are also less complicated to construct, facilitating better quality control. However, uncertainties still exist regarding the long-term effects of using straight-through details, with or without the dogleg, that could not be answered in the laboratory in the short time frame of the research project.

INTRODUCTION

In Iowa's climate, bridges expand and contract about an inch for every 100 feet of bridge length from the coldest day in winter to the hottest day in summer. One method of accommodating these thermal movements is through the use of expansion joints located on the superstructure (Figure 1), typically above either the abutments and/or the piers.

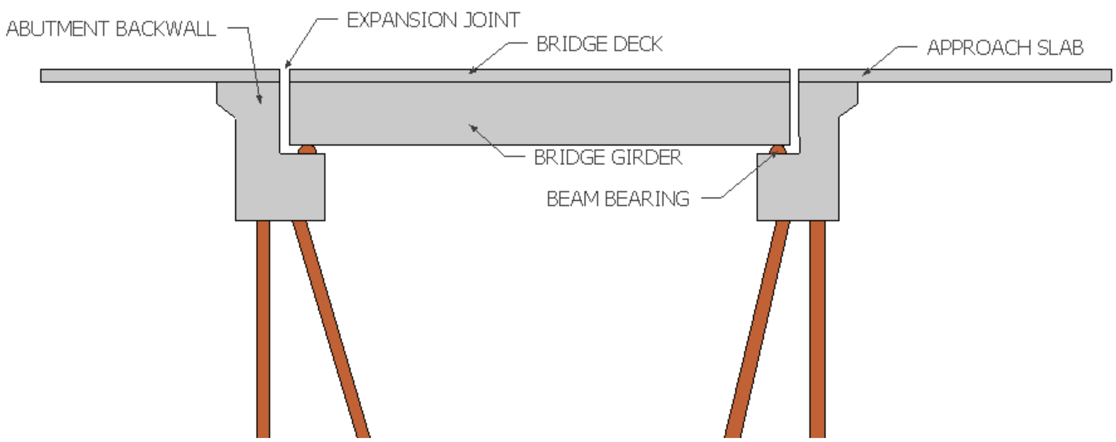


Figure 1. Bridge with expansion joints

Expansion joints are often outfitted with a flexible watertight seal that protects the substructure from water, chlorides, and debris infiltration from the bridge deck. The strip seal is a popular expansion joint device, commonly used in Iowa and many other states, that provides a watertight seal capable of accommodating 4 to 5 inches of movement. The strip seal system is comprised of steel extrusions that are cast in the concrete deck and a neoprene gland that fits into cavities in the extrusion (Figure 2).

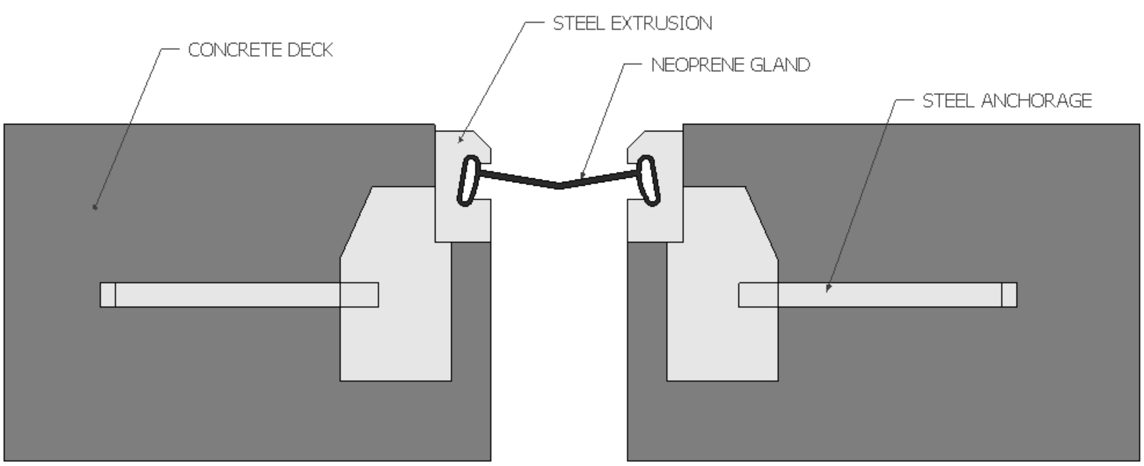


Figure 2. Strip seal cross-section

In Iowa, strip seals run transverse to the bridge deck and terminate by turning up and into the barrier rail in a two-step turn (Figure 3).

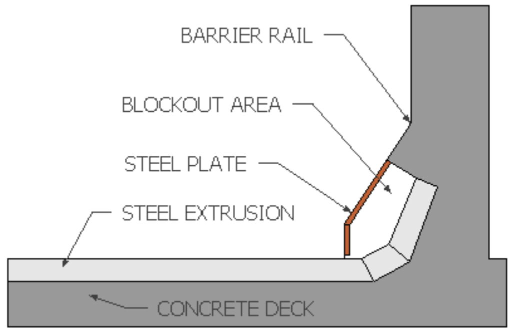


Figure 3. Strip seal termination section view

The turn-up prevents water from flowing over top of the strip seal, where it could then reach and cause deterioration to substructure elements below.

Strip seal termination details vary from state to state. Many states have strip seals that turn up in one step, some in two steps, at different angles, and some that run flat through the barrier rail and terminate at the exterior edge of the deck. Other states have strip seals that take horizontal "dogleg" bends in the deck before reaching the barrier rail. The many details and variations that exist have little to no written documentation on construction quality, joint performance, or maintenance requirements from either a laboratory or field perspective.

The current Iowa Department of Transportation (DOT) strip seal termination detail involves a turn-up of the strip seal at the barrier rail with a blockout area around the turn-up (Figure 4).

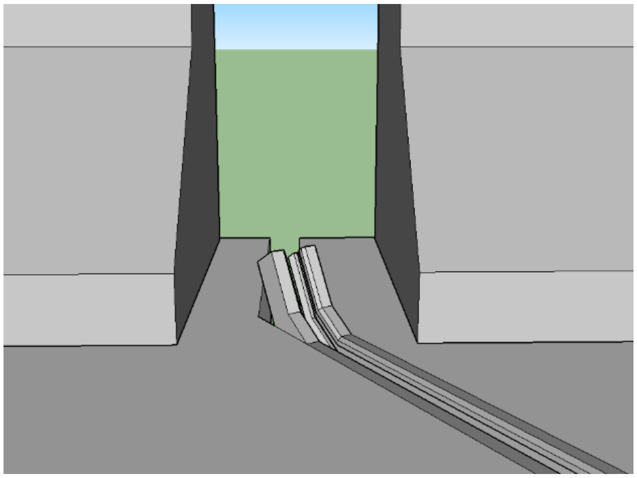


Figure 4. 3D strip seal termination

The inclusion of the blockout is to facilitate removal/replacement of the gland for maintenance purposes after initial construction. Construction begins with attaching the steel extrusions to the deck formwork in preparation for the deck pour. Once the deck concrete has been poured and finished, the barrier rail formwork is constructed and the rails are poured up to either side of the metal extrusions.

The last section of barrier rail is then typically formed by hand with special care taken to create a blockout area around the extrusions. Once the barrier rail is complete, the gland is installed into the steel extrusions and a steel plate is installed over the termination area to protect the strip seal blockout area from damage and to eliminate a potential vehicle or plow blade snag point.

To date, most post-construction issues arise from the blockout detail and how it is often constructed. Typical construction practice for creating the strip seal termination blockout is to leave a void in the barrier rail around and behind the strip seal turn-up (Figure 5) when the barrier rail is cast; the contractor then comes back and hand forms/packs the area behind the turn-up with concrete to accommodate the complex geometries present in the area.

Figure 5. Field construction of termination detail

Not only is this process cumbersome, but the resulting finish is often less than ideal (Figure 6).

Figure 6. Finished construction of termination detail

Research Goal, Tasks, and Scope

Engineers with the Iowa DOT Office of Bridges and Structures noticed that the construction quality of the strip seal termination detail on many of their bridges is less than desirable, especially on skewed bridges. Subsequently, they expressed a need to re-evaluate and possibly redesign the current Iowa DOT strip seal termination detail.

To work on this goal, the research team completed the following tasks:

1. Performed a literature search for strip seal termination details used by other states and a cursory literature review of strip seals.

2. Selected the most promising designs for the strip seal termination detail and subsequently constructed and tested them in the laboratory. The designs were evaluated on their constructability, water containment, and ease of gland installation.

3. Drafted and submitted to the Iowa DOT the final report documenting the findings of the laboratory testing and making final recommendations on strip seal termination detail designs for use on future structures.

LITERATURE REVIEW

Performance of Strip Seal Joints in Iowa Bridges 2001

A national survey was conducted by Bolluyt et al. (2001) and found that a significant number of states were experiencing premature failures in their bridge strip seals. In Iowa, a significant number of strip seals were found to have failed in less than 5 years of installation, which is considered premature because of the expected 15 to 20 year service life.

The authors set out to determine the causes of the premature failures in order to understand and minimize them in the future. The authors investigated 12 bridges with strip seal expansion joints, 11 of which were found to have a failure in the strip seal.

The two most common failures amongst the bridges studied were the neoprene gland pulling out from the extrusions and leaks developing in the gland. The authors determined that pullout failures often occur when the cavities in the extrusions were not cleaned properly before installing the neoprene gland. Cleaning the extrusions prior to gland placement is necessary for the gland and lubricant/adhesive to securely lock with the extrusion. The other problem with the strip seal was that the gland tends to fill with debris because of its inherent valley shape. Accumulation of debris in the gland allows vehicle and thermal loads to transfer into the gland, causing tears and resulting in a loss of water tightness.

Bolluyt, Kau, and Greimann recommended to the Iowa DOT that they switch to a termination detail similar to the one used by Missouri, Kansas, and South Dakota. These three states run the strip seal straight through the barrier rail, allowing water to drain from the gland and off the deck (Figures 11 through 14 later in this chapter).

If the strip seal termination were to allow for water drainage, this may be able to minimize the amount of water that leaks through the gland, even when small leaks are present. This detail may also facilitate the removal of debris from the gland, but further studies are needed to confirm this possibility.

The disadvantage of the straight-through detail, and what Iowa and many other states avoid, is that water draining from the edge of the deck at the strip seal termination may travel onto the substructure. To minimize or prevent this, three options have been used: a gutter can be installed to direct and control the water as it drains from the gland (Figure 14 later in this chapter), the gland can be run several inches past the deck so water runs/drips far enough away from the deck (Figure 13 later in this chapter) and rip rap can be strategically placed on the berms to prevent erosion.

FHWA Maintenance Manual for Bridge Decks 2003

The Federal Highway Administration (FHWA) Bridge Maintenance Training Reference Manual chapter on Deck Maintenance Procedures briefly discusses neoprene strip seals and explains that when properly installed, the strip seal device is watertight. The glands, however, are susceptible to a few long-term problems that compromise the strip seal's ability to keep the substructure dry.

Leaks develop when non-compressible debris are present in the joint as it closes, causing the neoprene gland to tear. Wheel loads from traffic also transfer through debris and into the gland causing tears. Common problem areas for leaks in the strip seal are due to manufacturing and installation errors at the gutter line, where sharp bends in the cross-section occur. Another problem, although it does not occur as often as problems with the gland, is the steel extrusions are hit a snowplow blade and break free from the concrete deck.

Iowa DOT Bridge Maintenance Manual 2014

In Iowa, strip seals are currently the preferred expansion joint device for thermal movements up to 4 inches. This is due to the strip seal's relatively good durability and performance when compared to other types of expansion joint devices.

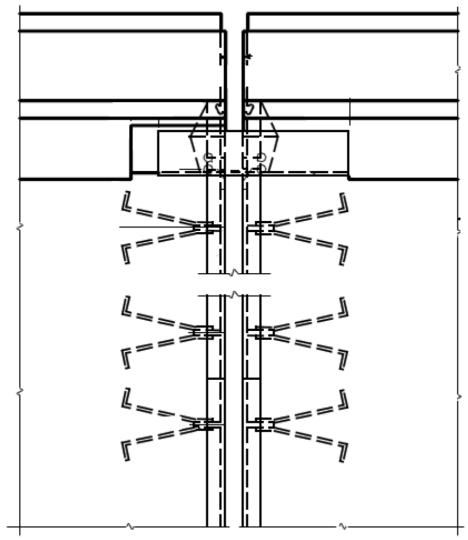
Even though the strip seal has relatively good performance, some strip seals fail prematurely in conditions where excess debris are present in the gland. To ensure the gland's full lifetime, cleaning and removal of debris should be performed periodically. The most important time for the cleaning and removal of debris is after winter, when the gland is in an open state and is filled with larger debris. The debris present in the gland when the bridge starts to expand in the summer, due to increasing temperatures, causes tearing of the gland and allows chloride-contaminated runoff to reach the substructure.

State Standards of Practice

Fifteen DOT termination details were found in a cursory search of online records. All of the details found were sorted into two main categories, which for the remainder of this report are referred to as the turn-up and the straight-through details. The turn-up detail gets its name because the steel extrusions are bent, or turned up, into the barrier rail, preventing water from flowing off the bridge deck. The straight-through detail gets its name because the steel extrusions run through the barrier rail and terminate flush with the outside edge of the deck, allowing water to flow off the bridge deck's edge. From these two categories, a number of different variations make each design unique, and these details are covered in the following sections.

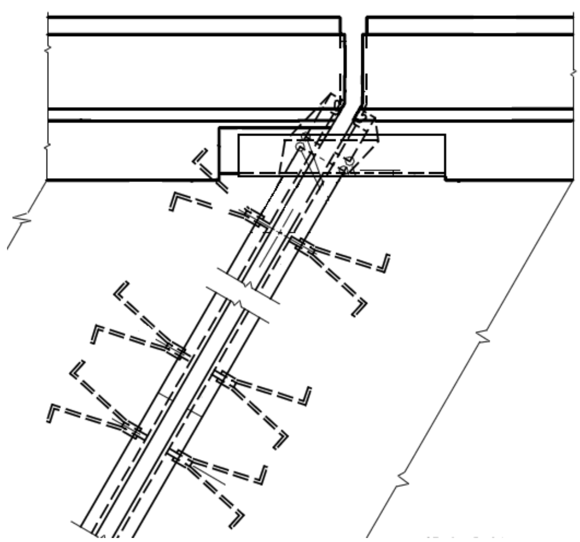
Iowa DOT Standard Practice April 2014

Currently, the Iowa DOT terminates the strip seal using the turn-up method (Figures 7 and 8) with two successive 30 degree bends to make the turn up more gradual (Figure 9). (Note: The detail text and notes were removed from the following drawings.)



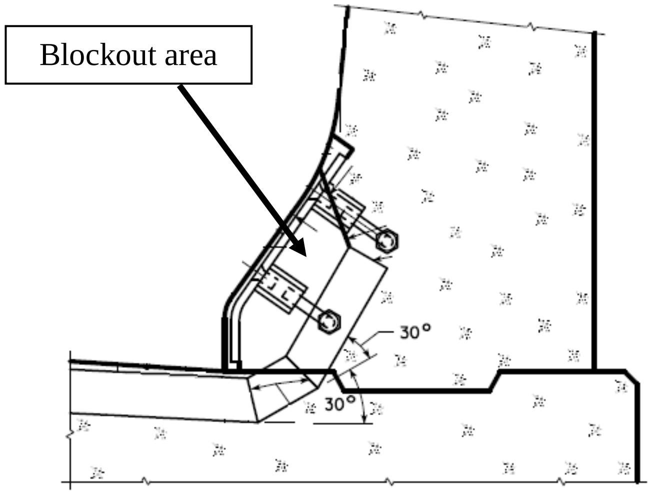
adapted from Iowa DOT 2014 Expansion Device Details

Figure 7. Iowa DOT strip seal plan view



adapted from Iowa DOT 2014 Expansion Device Details

Figure 8. Iowa DOT strip seal at skew plan view

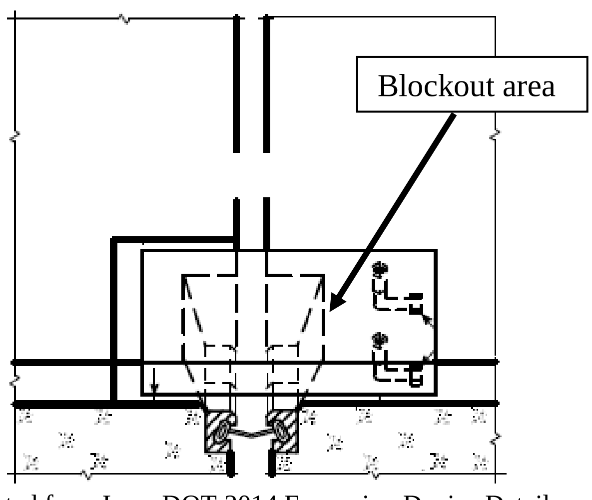


adapted from Iowa DOT 2014 Expansion Device Details

Figure 9. Iowa DOT strip seal section view of two-step turn

The design includes a void which is called the blockout area (Figure 9) between the face of the barrier rail and the turned up metal extrusion.

The blockout area, represented by dotted lines in Figure 10, is intended to allow working room to install, remove, and replace the neoprene gland both during initial construction and during future maintenance.



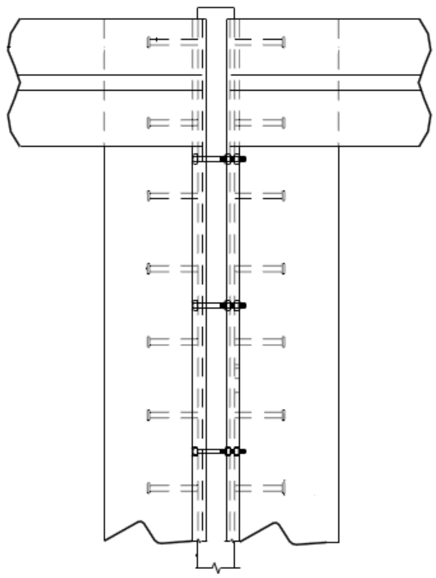
adapted from Iowa DOT 2014 Expansion Device Details

Figure 10. Iowa DOT strip seal blockout

A steel plate sits flush with the barrier rail and fits over this void to protect the termination of the strip seal as well as prevent damage from vehicles and snow plows.

Missouri and Kansas DOT Standard Practices

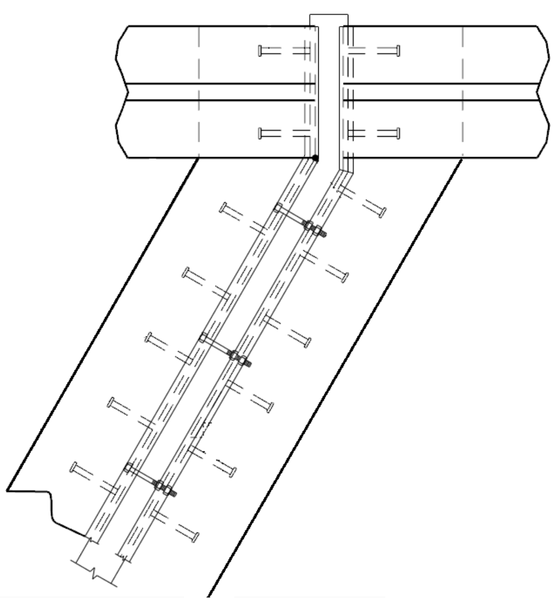
In Missouri and Kansas, the strip seal is run straight through the barrier rail and terminates flush with the end of the bridge deck (Figure 11).



adapted from MoDOT 2012 Details of Strip Seal at End Bent

Figure 11. Straight-through plan view

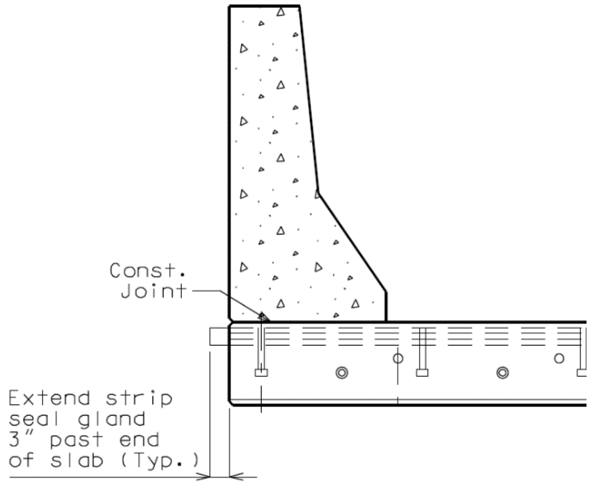
On skewed bridges, a horizontal "dogleg" bend in the steel extrusion is used to keep the geometry of the barrier rail square at the outside edge of the deck (Figure 12).



adapted from MoDOT 2012 Details of Strip Seal at End Bent

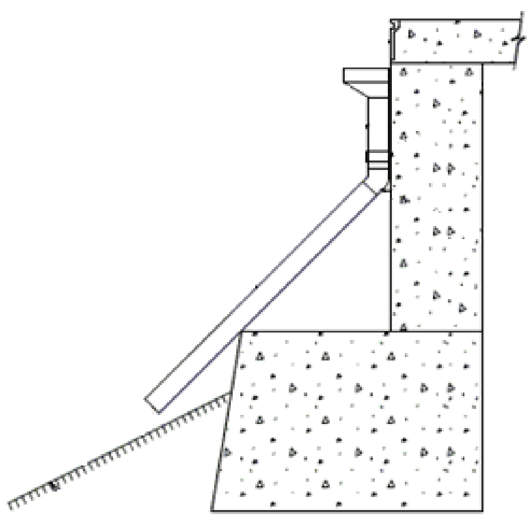
Figure 12. Straight-through at skew plan view

In order to minimize and prevent water from reaching the abutment below, Missouri runs the strip seal gland several inches past the barrier rail (Figure 13), whereas Kansas installs a gutter to collect and divert water away from the abutment (Figure 14).



adapted from MoDOT 2012 Details of Strip Seal at End Bent

Figure 13. Missouri DOT strip seal section view

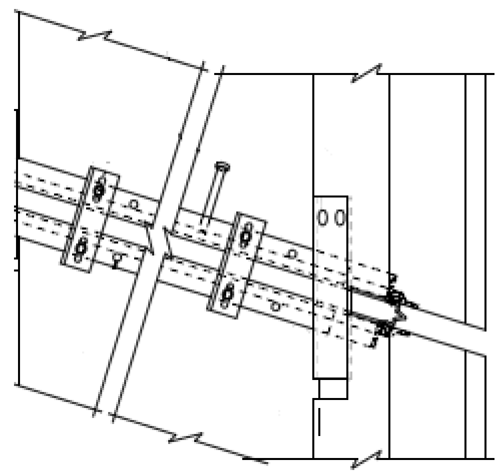


adapted from KDOT

Figure 14. Kansas DOT strip seal gutter detail

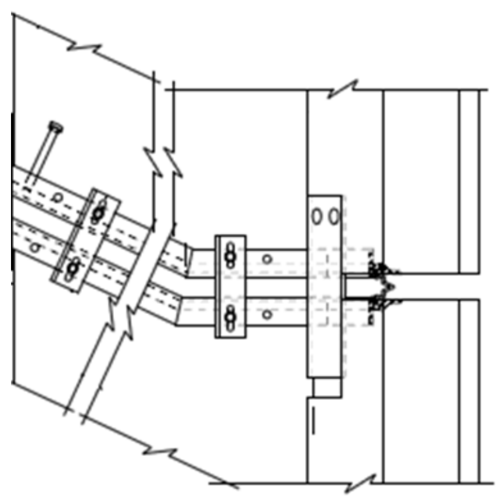
Arizona DOT Standard Practices

The Arizona termination detail uses a turn-up detail on bridges with a skew of less than or equal to 20 degrees (Figure 15) and a dogleg turn when the skew becomes greater than 20 degrees to simplify construction of the barrier rail around the strip seal extrusion (Figure 16).



adapted from ADOT 2009 Deck Joint Assembly Strip Seal

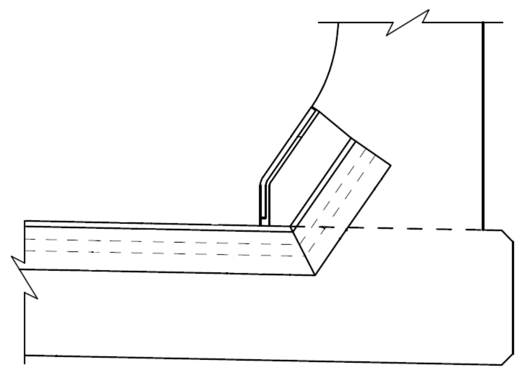
Figure 15. Arizona less than or equal to 20 degree skew plan view



adapted from ADOT 2009 Deck Joint Assembly Strip Seal

Figure 16. Arizona greater than 20 degree skew plan view

The Arizona termination detail features a one-step turn-up into the barrier rail, which matches the slope of the barrier rail face (Figure 17).



adapted from ADOT 2009 Deck Joint Assembly Strip Seal

Figure 17. Arizona one-step turn section view

STRIP SEAL MANUFACTURERS

Currently, the Iowa DOT allows contractors to choose between two strip seal manufacturers, D.S. Brown and Watson Bowman Acme, for installation on a new bridge. While the manufacturer's strip seal products are similar, there are a few subtle differences in geometry of the steel extrusion and, subsequently, working room required for installation of the gland.

D.S. Brown

A cross-section of the D.S. Brown strip seal gland and extrusion is shown in Figure 18.

Figure 18. D.S. Brown strip seal

A screwdriver or crowbar is used to install the lug of the gland into the extrusion. The direction of force required to install the gland, which is referred to as the pressing force, is shown by the arrow.

The technique used for installing the gland is shown in Figure 19, where the crowbar pries against the opposite face of the extrusion, pressing the gland into the extrusion, inch-by-inch along the length of the extrusion.

Figure 19. D.S. Brown gland installation

Watson Bowman Acme

The Watson Bowman Acme strip seal product is shown in Figure 20.

Figure 20. Watson Bowman Acme strip seal

The direction of force, which is referred to as the lifting force, required to install the gland is shown with the arrow in the figure. For this strip seal, a special tool with a bent and tapered end, provided by the manufacturer, is used to install the lug of the gland into the extrusion (Figure 21).

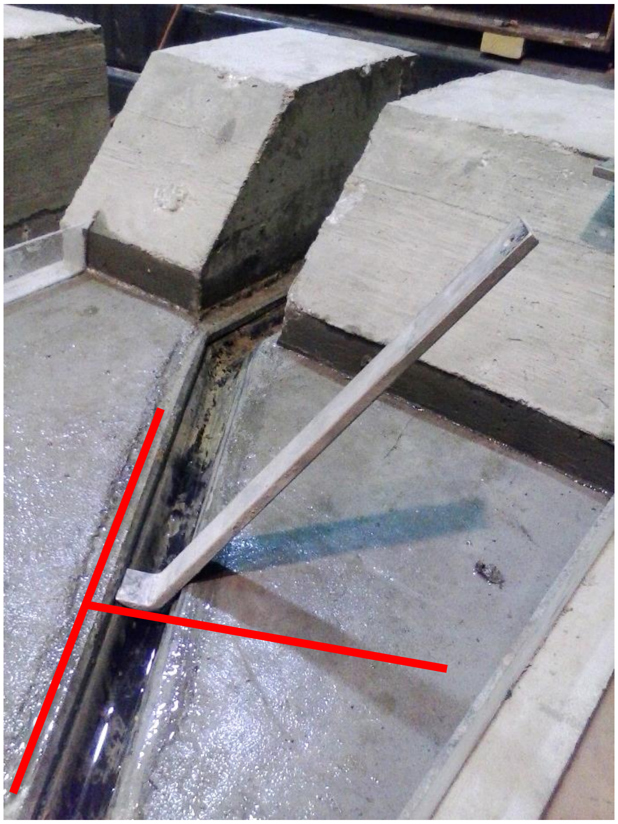


Figure 21. Watson Bowman Acme gland installation

As shown, the tool is used to pry against the opposite face of the extrusion, lifting the lug up and into the extrusion. For this tool to be effective, the tool must be perpendicular to the length of the strip seal extrusion, as shown with the lines in Figure 21. Two installation tools can be used at once for a faster installation, using one tool to hold the gland in place while the other tool lifts the gland into the extrusion.

DETAIL SELECTION AND SPECIMEN DESIGN

Based on the literature search and discussions with the project technical advisory committee (TAC), the following strip seal termination details were selected for evaluation in the laboratory for testing: turn-up (Iowa's current standard detail), straight-through, dogleg, and bentonite. All laboratory specimens were approximately 3 feet wide by 3.5 feet long, with the addition of a one foot tall barrier rail section. The specimen size was chosen so that proper evaluation of the termination detail could be made while also maximizing space in the laboratory.

Given that the Iowa DOT experiences the most severe problems with the strip seal termination detail on skewed bridges, all laboratory specimens were constructed at a 30 degree skew. This ensured that recommendations for new or improved details were tested under the most critical circumstances.

Turn-Up Termination Detail

The turn-up termination detail bends the strip seal extrusion up and into the barrier rail in two successive 30 degree bends. The purpose of this upturn is to prevent water from flowing off the bridge deck at the location of the strip seal, where it may end up on critical substructure elements that are susceptible to corrosion. A section view of the turn-up laboratory specimen is shown in Figure 22, and a plan view of it is shown in Figure 23.

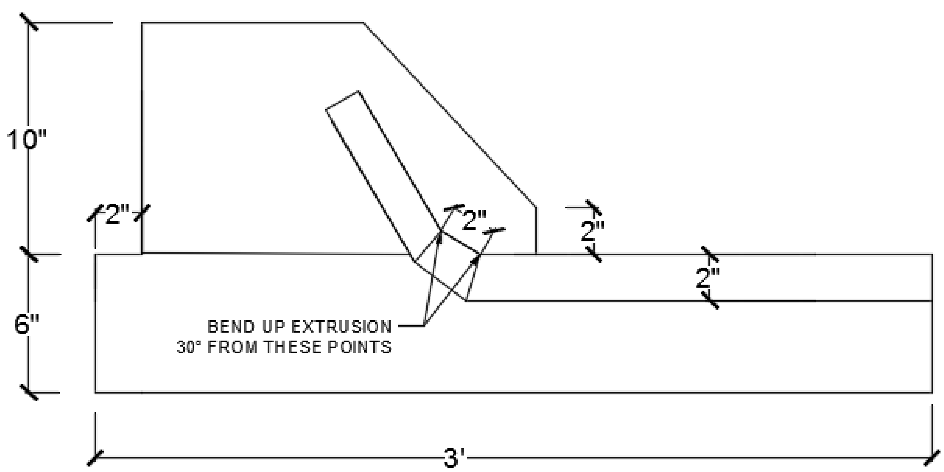


Figure 22. Turn-up specimen section view

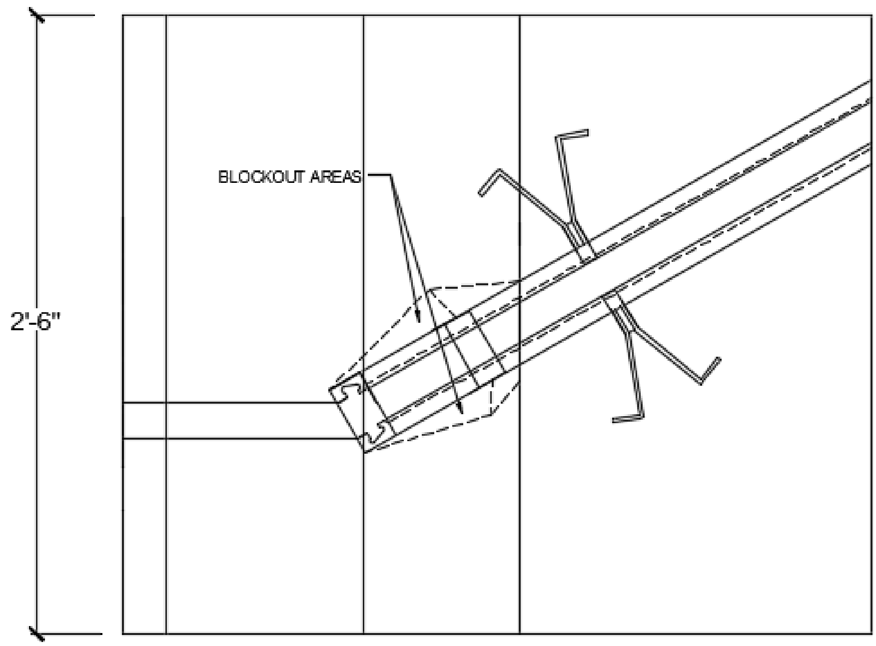


Figure 23. Strip seal specimen plan view

Again, this is the current detail specified by the Iowa DOT for new bridge construction. Note that the strip seal continues straight into the barrier rail with no horizontal turn.

Straight-Through Termination Detail

The straight-through detail runs the strip seal flat through the barrier rail and terminates the extrusion flush with the outside edge of the deck. The gland can be run a few additional inches past the deck to help displace runoff water away from the deck, as shown in a section view of the specimen in Figure 24; a plan view of the specimen is shown Figure 25.

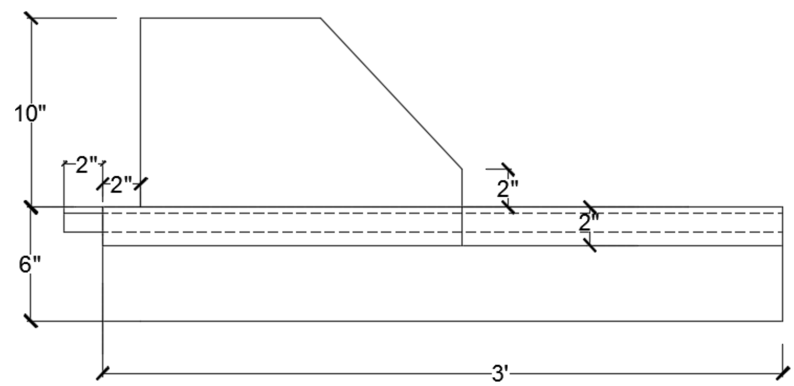


Figure 24. Straight-through specimen section view

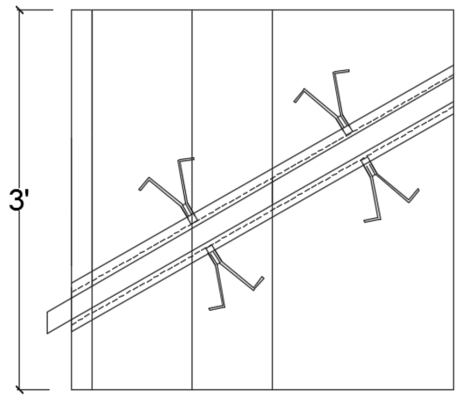


Figure 25. Straight-through specimen plan view

The benefit of this termination detail is that it simplifies construction of the barrier rail at the location of the strip seal. Additional benefits of this detail may be that water can drain from the strip seal, so the water is not allowed to pond in the gland, as there are often small tears and leaks that develop as a result of several factors.

Potential disadvantages of this detail are that the water, and chlorides in the winter months, that drain off the strip seal termination may end up dripping on the substructure below if proper water management techniques are not implemented.

Examples of mitigation techniques include drip edges, extending the gland past the edge of the concrete deck, and installing gutters at the termination of the strip seal to direct contaminated water away from the substructure.

Like the previous detail, there was no horizontal turn in the strip seal at the barrier rail; it was simply run straight through.

Dogleg Termination Detail

The dogleg termination detail is much like the straight-through detail, and the only difference is in the horizontal dogleg bend that the extrusion takes in the deck before entering the barrier rail (Figure 26).

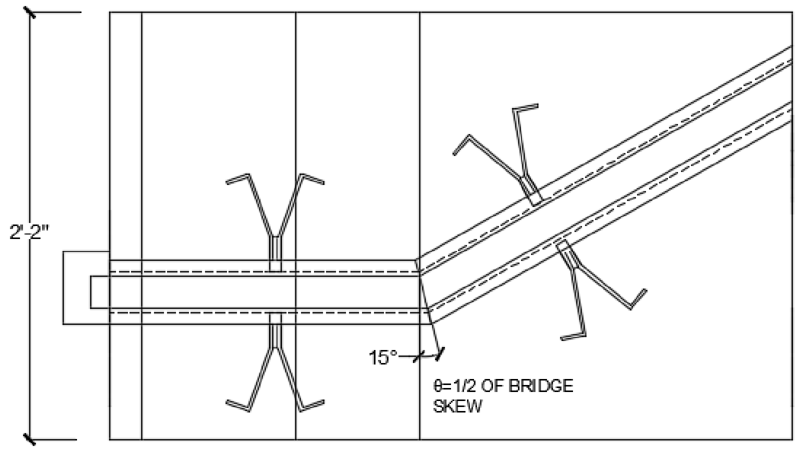


Figure 26. Dogleg specimen plan view

This bend makes the break in the barrier rail rectangular to simplify construction of the barrier rail. However, this bend also creates a change in geometry in the deck, which creates a slightly more complicated deck to construct. In addition, at high skew angles, the dogleg presents issues with installation of the gland, which are discussed later.

Bentonite Option

The bentonite option utilizes either the straight-through or dogleg design, where the strip seal allows water to drain from the bridge deck. However, with the bentonite option, steel plate dams are attached on the front and back faces of the barrier rail and granular bentonite is placed within the void in the barrier rail on top of the strip seal, as shown in Figure 27.

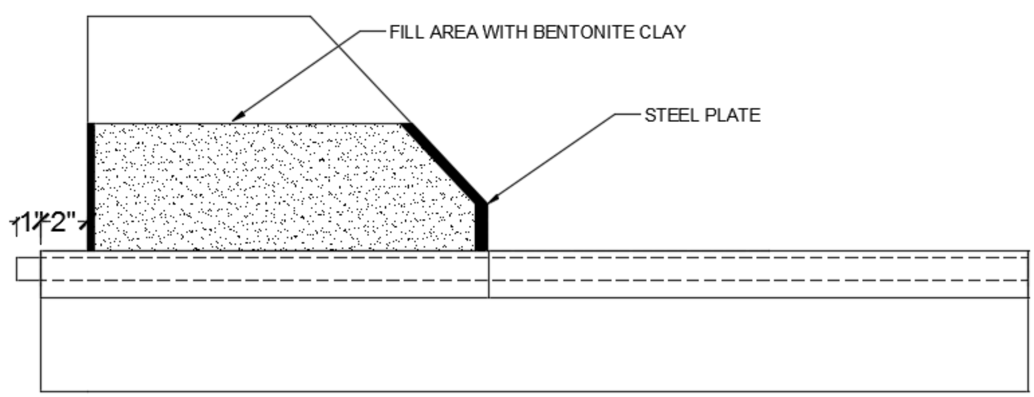


Figure 27. Bentonite specimen section view

Granular bentonite is a highly expansive clay when exposed to moisture, so as moisture infiltrates the strip seal cavity in the barrier rail, the bentonite expands blocking further ingress of moisture as well as reducing and/or eliminating escaping runoff out the back of the strip seal. The clay is used in many different applications to create watertight seals. Here, the bentonite serves the purpose of preventing or limiting water from running off the bridge deck.

LABORATORY TESTING

Testing Methodology

In order to evaluate and compare the termination details selected for evaluation, three criteria were established by the research team: constructability of the termination detail, ease of gland installation and replacement, and water containment.

Constructability evaluates the required effort to form and pour the deck and barrier rail concrete around the metal extrusions of the strip seal in the termination region and measures overall construction quality of the completed detail.

Gland installation evaluates the working room provided by the detail, so that the gland can be installed efficiently and properly into the termination area whether it be during initial construction or in the future when removal and replacement of the gland is required for maintenance.

To evaluate water containment, dams were placed on the specimen and a 30 minute ponding test was performed. The dam provided the research team the ability to pond three inches of standing water above the strip seal so the underside of the specimen could be inspected for leaks. A ponding test is considered to be a failure when droplets of water are visible underneath the joint.

For each design alternative, two lab specimens were constructed, one using the D.S. Brown strip seal and the other using the Watson Bowman Acme strip seal. Figure 28 shows the cluster of laboratory specimens before testing.

Figure 28. Laboratory specimens for testing

Turn-Up Termination Detail

The turn-up terminiation detail was constructed in the laboratory to serve as a control specimen and establish a baseline for constructability, gland installation, and water containment. Construction of the deck and barrier rail around the turn-up portion of the strip seal involved complicated geometries, and subsequently, was a relatively time consuming process.

The most difficult aspect was not the complexities of constructing the barrier rail or the blockout itself, but understanding and visualizing what the finished product needed to look like. Little information is available related to how much blockout area is required to facilitate proper installation of the gland, so this aspect of the detail and construction process was investigated prior to specimen fabrication.

To assist, a three-dimensional (3D) printout of a strip seal blockout was obtained from the Iowa DOT Office of Bridges and Structures. In addition, several bridge sites were visited to visually examine the strip seal terminations and blockouts for documentation of blockout size, shape, and condition.

Construction

Construction of the turn-up detail began with erecting the deck formwork and duct taping over the cavity on the metal extrusion to ensure concrete would not fill or contaminate the cavity during the concrete pour. Next, the metal extrusions were attached to the deck formwork and the concrete was poured and finished with a trowel (Figure 29).

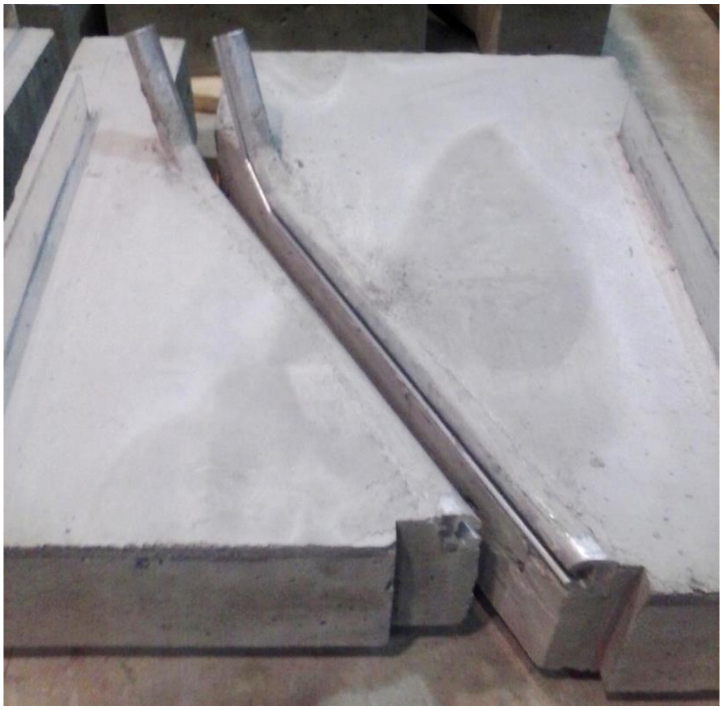


Figure 29. Strip seal construction before barrier rail placement

Next, the barrier rail was constructed around the turn-up portion of the extrusion, formwork was erected (Figure 30), and the blockout area, which facilitates gland installation, was created.

Figure 30. Barrier rail formwork

To thoroughly investigate creation of the blockout, two methods of creation were tested. The first method used blue insulation board, which was cut to the rough shape and placed in front of the extrusions (Figure 31).

Figure 31. Blue insulation board used for blockout

Additional slivers and scrap pieces of the board were then used to detail the rest of the blockout area (Figure 32).

Figure 32. Completed blockout area using insulation board

The second option investigated for creating the blockout area was spray foam from a can. The foam was sprayed into a closed void the shape of the blockout and left to cure overnight (Figure 33).

Figure 33. Expanding foam in a can

The spray foam bonded to the plywood used in creating the blockout area (Figure 34), which then tore the foam open when removed.

Figure 34. Plywood used to create foam enclosure

A second can was used to spray another lift of foam and, once cured, was trimmed to the desired shape of the blockout; then the concrete barrier rail was poured (Figure 35).

Figure 35. Barrier rail with spray foam

The specimen using the blue insulation board and the spray foam are shown completed in Figures 36 and 37, respectively.

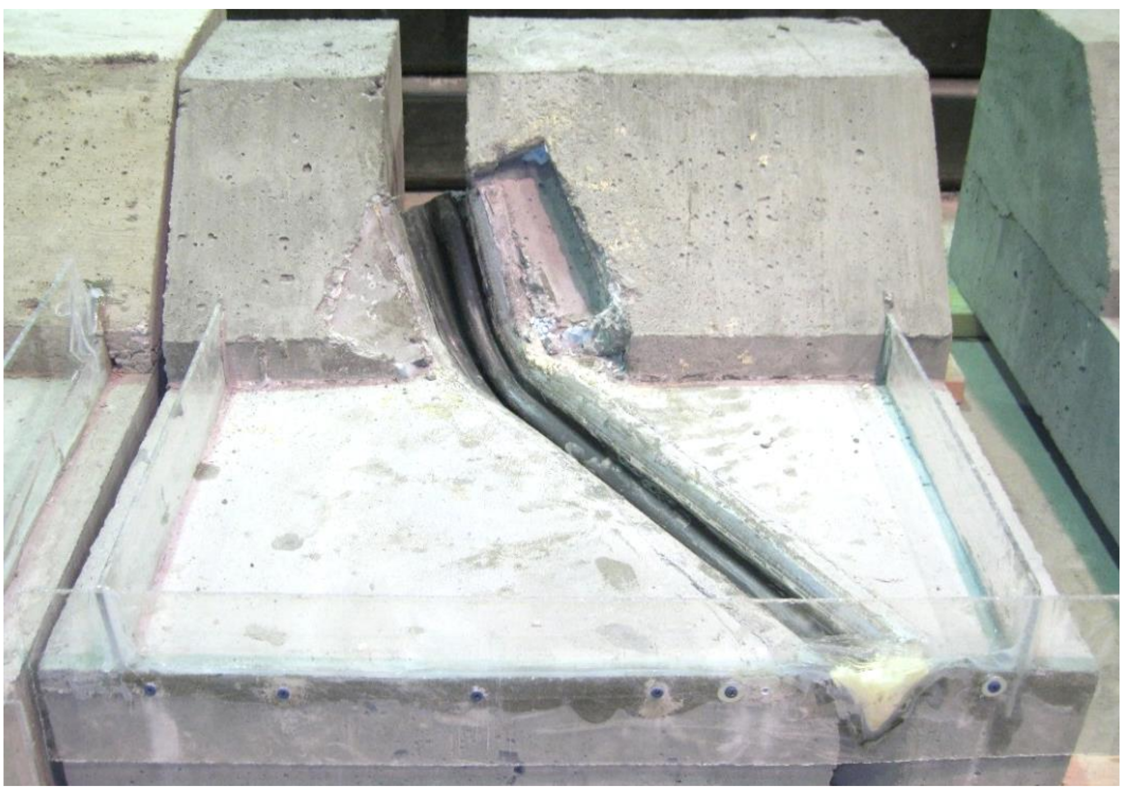


Figure 36. Turn-up specimen with blockout formed using blue insulation board

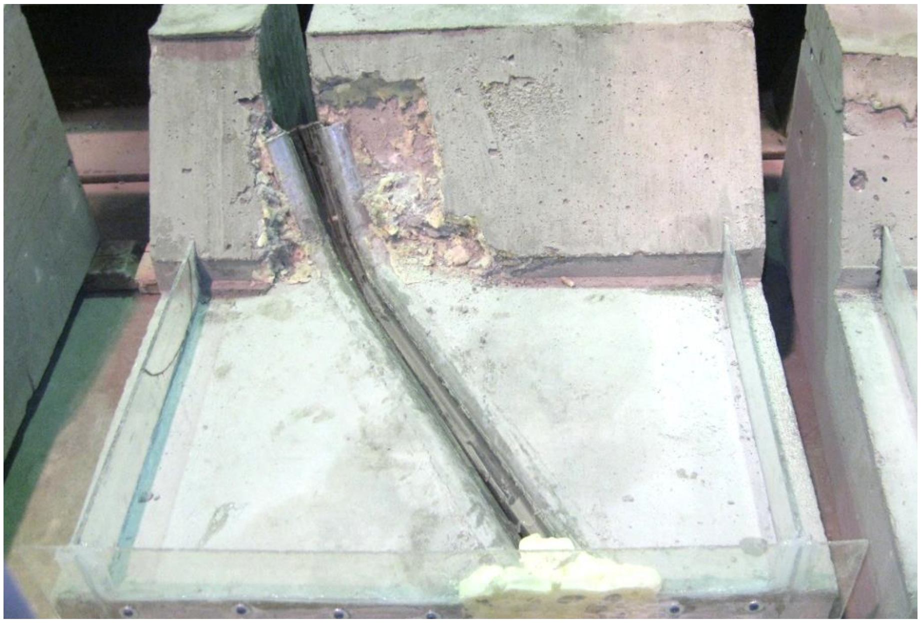


Figure 37. Turn-up specimen with blockout formed using spray foam

The blue foam option was found to be the best option because it facilitates speed in construction and removal.

The construction procedure presented, which was used in this laboratory investigation, is not always the procedure used in field construction. According to engineers with the Iowa DOT, contractors often construct the barrier rail around the turn-up portions of the strip seal while leaving a void around and behind the strip seal turn-up, as shown earlier in Figure 5.

Contractors will subsequently hand pack and form concrete into the void to finish the detail, which is not only cumbersome, but often results in a surface finish that is less than ideal. This laboratory research illustrates that these steps can be eliminated by cutting the void material to the shape of the blockout prior to pouring the barrier rail.

Deck Pour Encapsulation

The deck pour encapsulation method is an alternate construction sequence to build the current Iowa termination detail. This method encapsulates the turn-up portion of the strip seal with concrete at the same time the deck is poured (Figures 38 and 39).

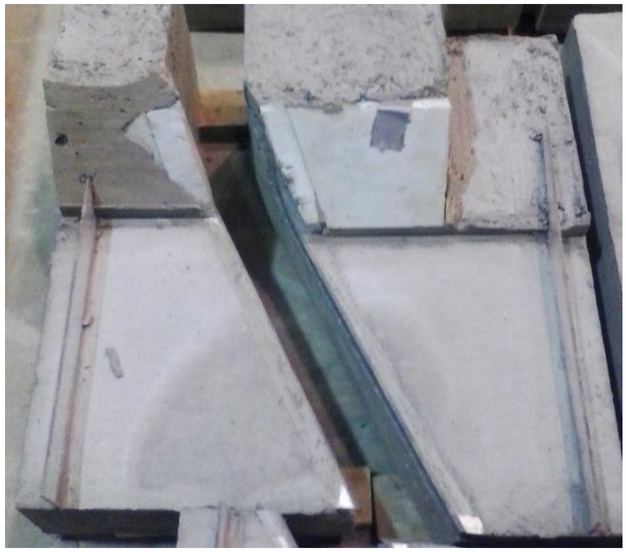


Figure 38. Turn-up portion of the strip seal with foam encapsulated in concrete at the same time the deck was poured

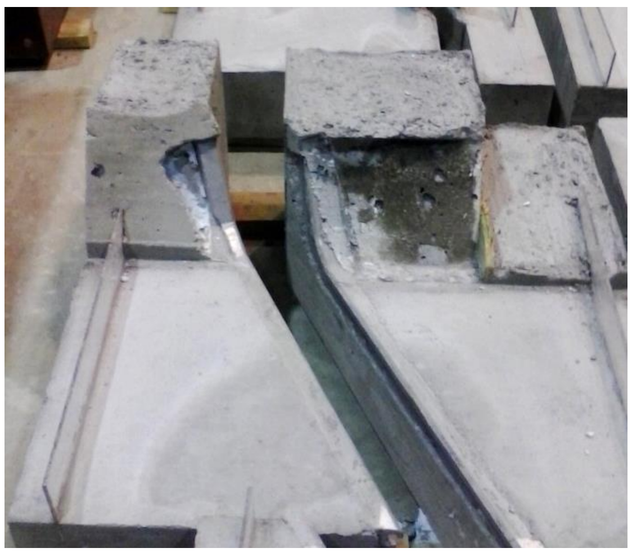


Figure 39. Turn-up portion of the strip seal encapsulated in concrete at the same time the deck was poured

This modified sequence allows the full barrier rail to be cast over the top of the strip seal and resulting encapsulation in one step (Figure 40), whether the rail is slip formed or formed by hand.

Figure 40. Completed barrier rail

The deck pour encapsulation also eliminates the complexities that result from blocking out the area around the strip seal turn-up and hand packing concrete into the void.

One question that came up during construction of the deck pour encapsulation is if the additional head from the concrete in the elevated pour would push out and create a rise in the deck. Some rise in the deck concrete was detected while filling the encapsulation area, which was quickly addressed using a small piece of plywood and dead weight on top. After waiting a few minutes for the concrete to set, the plywood and dead weight were removed and the concrete was trowel finished as normal.

The deck pour encapsulation was created to provide contractors with a simple construction method, which eliminated the hand packing of concrete around the strip seal. The method worked well in the laboratory and successfully eliminated the hand packing of the concrete, which would allow for the full barrier rail to be cast at once in the field, whether the rail be slip or hand formed. Overall, this alternative method of construction was no more or less difficult to construct when compared to the construction of the turn-up specimens in this laboratory study.

Gland Installation

Initially, the gap in the bridge deck between the strip seal extrusions was set to 2 inches, which is a common width that contractor's work with in the field. At this spacing, no problems were encountered installing the gland on the two traditional turn-up specimens or the deck pour encapsulation specimen. The blockout areas provided more than enough working room to install the gland in the area of the strip seal termination. There was no appreciable difference in level of difficulty for installing the gland when comparing the D.S. Brown and Watson Bowman Acme manufacturers on the turn-up specimens.

Ponding Test

Of the three turn-up specimens created, only one specimen experienced leaking. The leak found was located between the face of the metal extrusion and the barrier rail and, therefore, was not a result of a faulty seal or installation of the gland, but rather inadequate concrete consolidation around the extrusion. The spray foam used in creating the blockout region bonded to the metal extrusion, which created a penetrable layer between the concrete and the extrusion.

To verify that the leak was indeed occurring between the extrusion and the barrier rail, caulking was placed over the area and the ponding test was repeated; the subsequent ponding test resulted in no leaks. To prevent this type of leak in the future, if spray foam is utilized, the face of the metal extrusion should be scraped and scrubbed clean of all spray foam residue prior to casting the barrier rail.

Modified Blockout Region

One unknown going into the construction of the Iowa turn-up detail was concerning the size of the blockout region necessary to allow for the proper range of motion for the installation tools to install the gland. Preliminary experimentation with the specimen created in the laboratory and the gland installation tools indicated that the area directly in front of the metal extrusions, as illustrated in Figure 41, was sufficient to facilitate proper installation of the gland (and, in other words, no blockout is necessary).

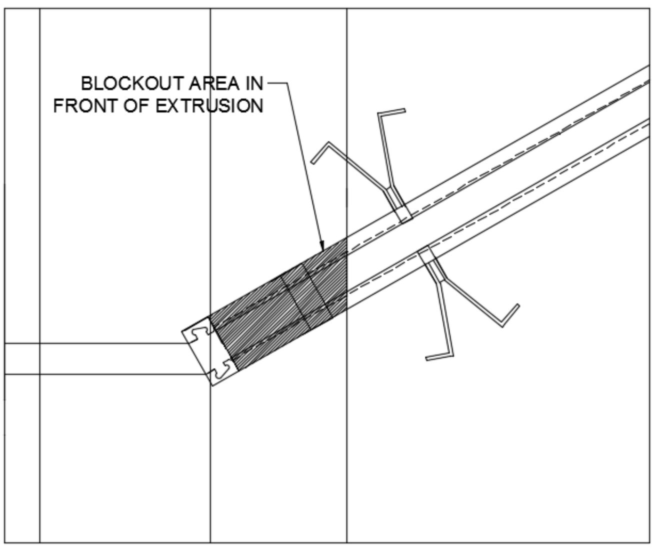


Figure 41. New blockout detail

To test this idea, wood was attached in the blockout area to reduce the size of the working room, only leaving room directly in front of the extrusions (Figure 42).

Figure 42. Wood attached in the blockout area to reduce the size of the working room, only leaving room directly in front of the extrusions

With the smaller blockout area in place, the gland was removed and re-installed successfully. In fact, the research team found that the smaller blockout area improved installation of the gland because the new surface provided better tool leverages. This smaller blockout region was successfully tested in the laboratory on a Watson Bowman Acme strip seal, and based on the results from other laboratory specimens tested, the D.S. Brown product can be installed into even tighter areas just as successfully.

A resulting modification that could be made to the Iowa detail from this information is redrawing the blockout area, or specifying on the plans that the blockout area only needs to be as wide as the metal extrusions. This modification simplifies the detail for contractors with the same end result and may lead to an overall better finished product.

Straight-Through and Dogleg Termination Detail

Before constructing the straight-through and dogleg detail specimens in the laboratory, engineers with the Iowa DOT expressed two concerns with this design. One concern is that water draining from the termination of the strip seal may reach the abutment below, causing additional long-term problems for the bridge. Second, at least one engineer expressed skepticism regarding the ability to install the neoprene gland in the narrow gap between the barrier rails.

The D.S. Brown and Watson Bowman Acme strip seals were investigated for each detail to better understand the differences in installation tools and required working room, which would be limited between the barrier rails.

Construction

Construction of the straight-through and dogleg specimens began with forming and pouring the concrete deck (Figures 43 and 44).

Figure 43. Deck formwork for straight-through and dogleg specimens

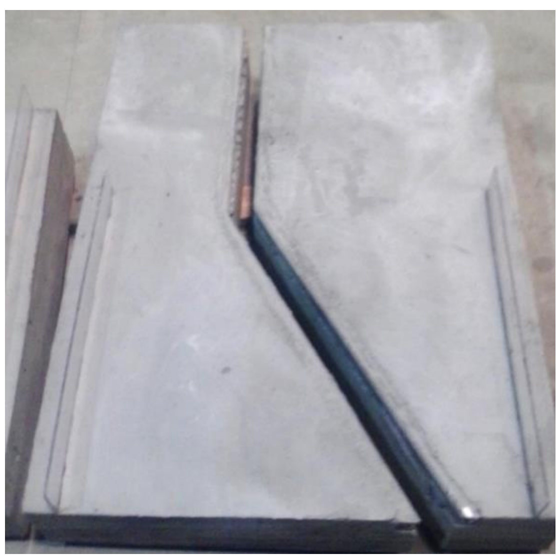


Figure 44. Finished concrete deck for straight-through and dogleg specimens

Formwork for the barrier rail was erected and blue insulation board was cut to the shape of the barrier rail to create a break in the barrier rail (Figure 45).

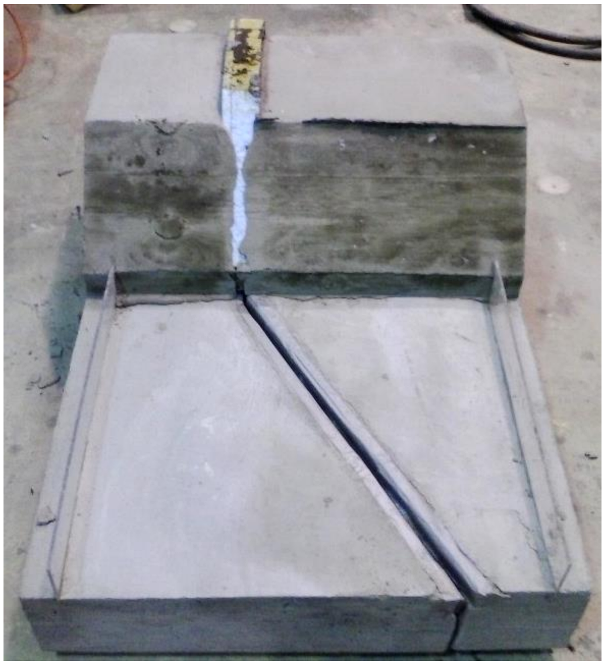


Figure 45. Barrier rail with foam board to create the break in the rail

Using a hammer and putty knife, the insulation board was removed from the rail with ease (Figure 46).

Figure 46. Finished barrier rail for straight-through and dogleg detail

The dogleg and straight-through specimens were easier overall to construct in the laboratory than the turn-up detail specimens. The straight-through detail has simple geometries at the termination of the strip seal, which make it straightforward to read, visualize, and construct from the plans.

The researchers constructed four straight-through and dogleg specimens in the laboratory (Figures 47 through 50).

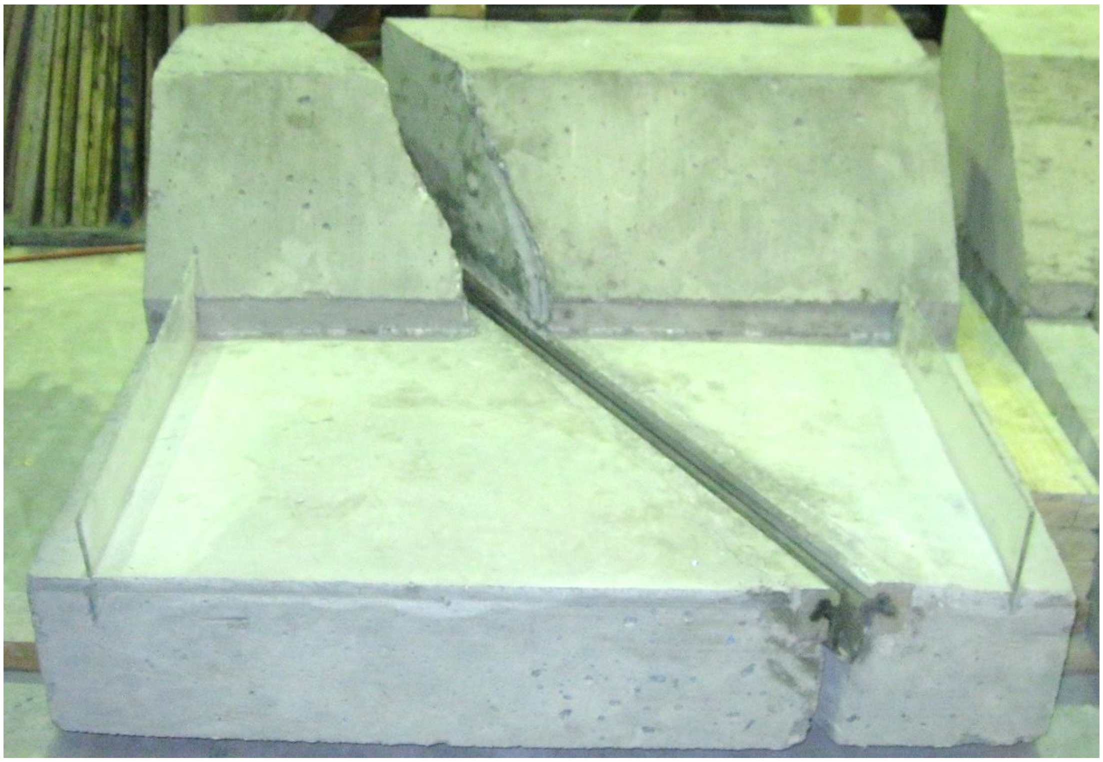


Figure 47. Straight-through terimation specimen using Watson Bowman Acme seal

Figure 48. Straight-through termination specimen using D.S. Brown seal

Figure 49. Straight-through dogleg termination specimen using Watson Bowman Acme seal

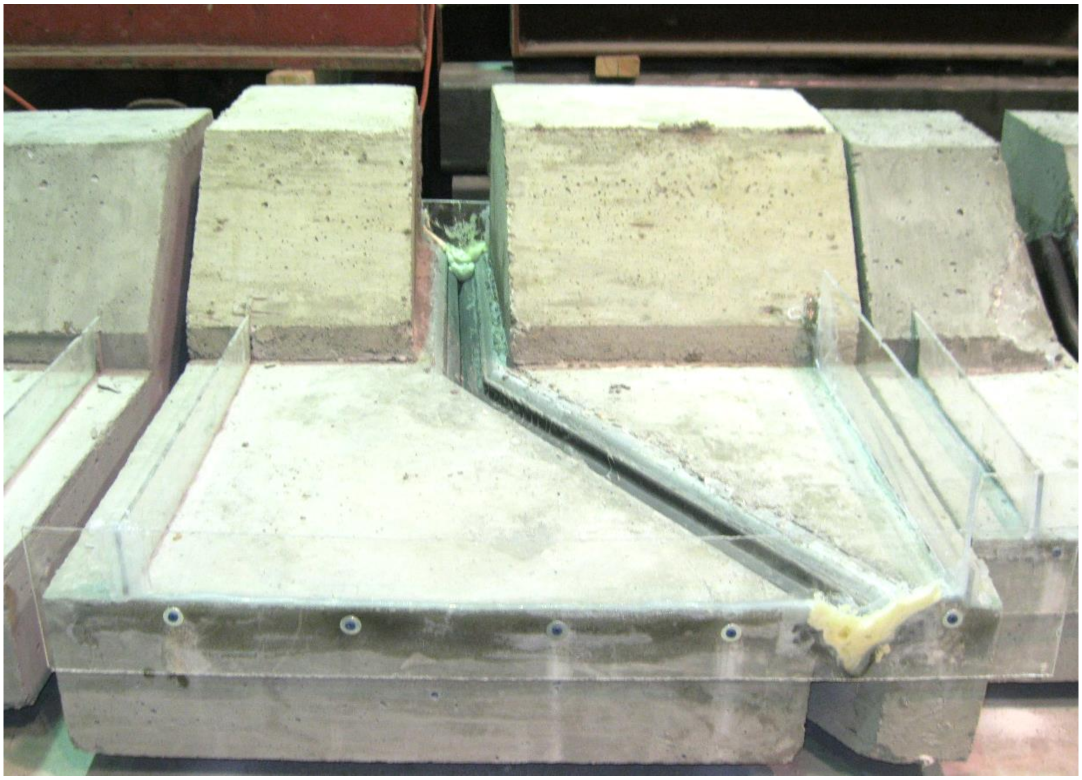


Figure 50. Straight-through dogleg termination specimen using D.S. Brown seal

Comparing the dogleg and straight-through (no-turn) details, the researchers found no appreciable difference in the level of construction difficulty in building the specimens. The deck formwork was slightly more challenging on the dogleg specimen; whereas, the barrier rail formwork was slightly more difficult on the straight-through specimen.

Gland Installation

As previously mentioned, engineers at the Iowa DOT were concerned that there would not be enough working room between the barrier rails to install the gland. Given that the barrier rails were only constructed to mid-height, blocks were placed on top of the rails to simulate full-height rails while the glands were installed in the laboratory. The specimens were set up with a 2 inch gap between the strip seal extrusions for gland installation; this resulted in a 4 inch gap in between the barrier rails, given that the barrier rails were constructed up to the back face of each strip seal extrusion.

The differences between the D.S. Brown and Watson Bowman Acme seals became pronounced during the installation of the glands between the barrier rails. The D.S. Brown strip seal, which utilized a crow bar to press the gland into the extrusion, worked well between the rails, taking approximately 10 minutes to install. The Watson Bowman Acme strip seal using the installation tool provided by the manufacturer was much more difficult to install between the barrier rails; this installation took approximately 80 minutes. The fact that the installation tool only worked when perpendicular to the strip seal extrusion made it difficult to leverage the tool between the barrier rails (Figure 51).

Figure 51. Watson Bowman Acme gland installation tool limited by mid-height barrier rail

Using blocks of wood, the angle and leverages of the tool could be manipulated and the gland installed (Figure 52); however, the process was time consuming and tedious.

Figure 52. Wood blocking used between mid-height barrier rails with Watson Bowman Acme gland installation tool

The D.S. Brown gland could be pressed into the extrusion with a crowbar from any angle, allowing the installer to easily leverage the tool and work outside of the barrier rail. In fact, the front face of the barrier rail served as an excellent prying surface that made the installation of the D.S. Brown gland even faster than when no barrier rail was available to pry on (Figure 53).

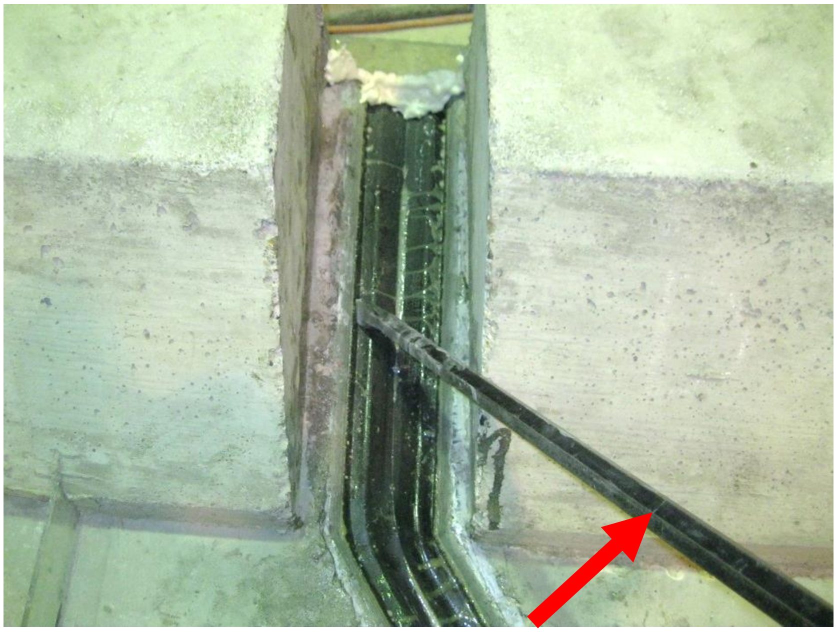


Figure 53. Use of a crowbar to install D.S. Brown gland

The arrow in the figure shows the force applied to the crowbar to press the gland into the extrusion.

Ponding Tests

Three of the four straight-through specimens passed the 30 minute ponding test. The dogleg specimen with a Watson Bowman Acme strip seal failed due to a leak that occurred in the dogleg bend of the extrusion (Figure 54).

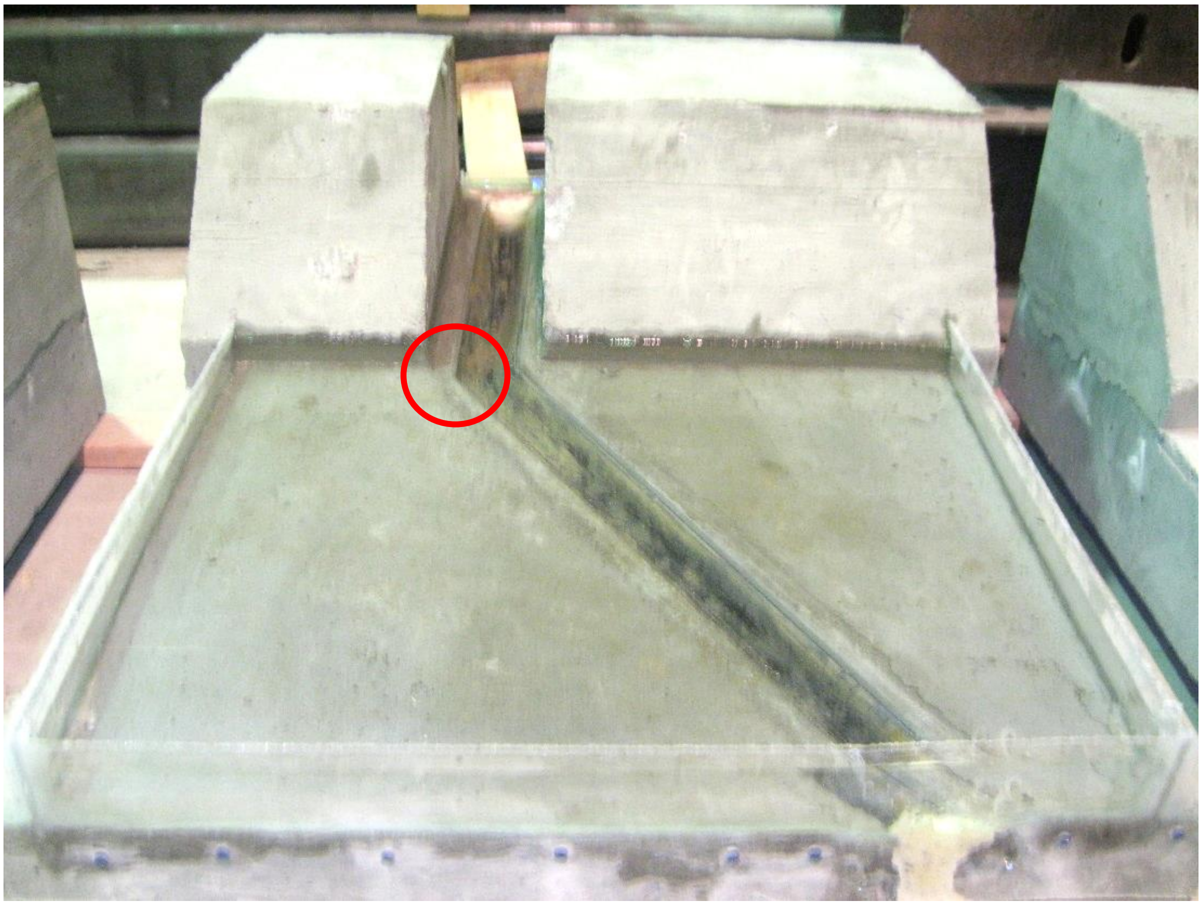


Figure 54. Watson Bowman Acme dogleg specimen with leaking gland

Inspection of the gland revealed that the gland had not been pushed into the extrusion 100 percent and could be pushed further into it (Figure 55).

Figure 55. Improper gland installation causing leak in Watson Bowman Acme dogleg specimen

Using the installation tool, the gland was forced into the extrusion an additional amount and the ponding test was repeated; the subsequent ponding test was again unsuccessful. (Figure 56).

Figure 56. Second attempt to properly install gland in Watson Bowman Acme dogleg specimen

A third attempt was made, completely removing and reinstalling the neoprene gland. Again, the specimen leaked through the same area on the dogleg bend. A final attempt was made at removing and reinstalling the gland; however, the gland was punctured at the dogleg bend of the metal extrusion during this final attempt, and no subsequent attempts were made to install the gland into the extrusion on this specimen.

Debris Removal

Bolluyt et al. (2001) noted that a completely horizontal strip seal may facilitate the removal of debris that often and in most cases inevitably accrues in the gland valley. All field investigations undertaken by Bolluyt et al. during this research found evidence of debris accumulation. To investigate this evidence in the laboratory on this project, the researchers gathered a mixture of sand, dirt, leaves, and debris and placed it on top of the strip seal (Figure 57).

Figure 57. Mixture of dry debris placed on top of strip seal specimen

A garden hose was then used to simulate rain. After sprinkling water for 15 minutes, very little, if any, debris had been removed. To simulate water flowing heavily off of the bridge, buckets of water were dumped onto the specimen and allowed to drain over the strip seal. After this simulation, again little debris had been washed away (Figure 58).

Figure 58. Mixture of debris on top of strip seal specimen after simulating water flowing heavily off the bridge

Only the finest particles were leaving the gland with the water, and the rest of the debris appeared to have consolidated within the valley of the gland. The researchers checked behind the specimen during and after the simulations. No debris landed behind the specimen, so it is unlikely that water passing over the gland would remove debris.

Bentonite Option Termination Detail

In the laboratory testing, plywood was attached to the front and back of the barrier rail on the straight-through specimen, simulating the steel plate commonly used in the field, to cover the gap in the barrier rail and retain a fill of granular bentonite (Figure 59).

Figure 59. Bentonite option termination specimen

The granular bentonite (Figure 60) was poured between the barrier rails and a ponding test was conducted (Figure 61).

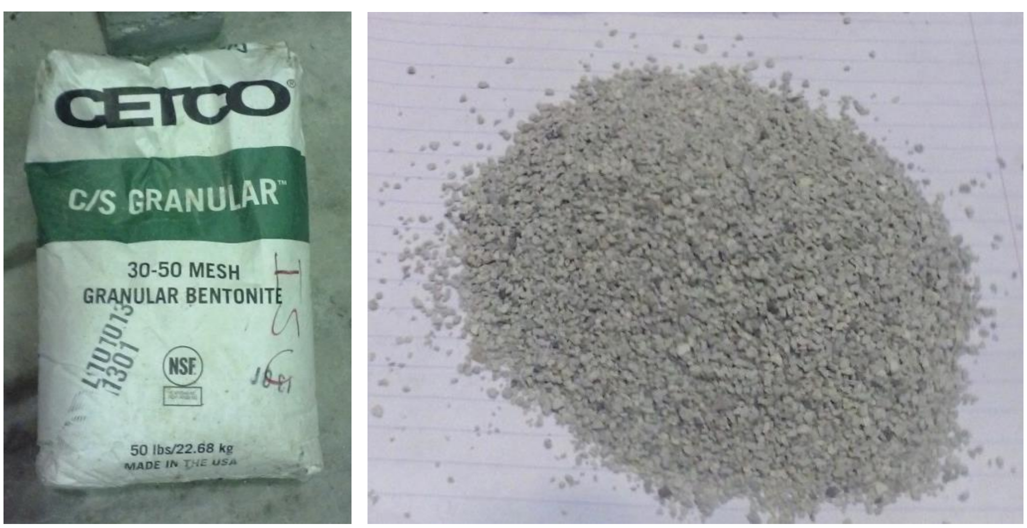


Figure 60. Granular bentonite

Figure 61. Bentonite option specimen during ponding test

The dry bentonite swelled up as it came in contact with the ponding water that seeped between the gland and the plywood cover, creating a seal between the barrier rails and successfully containing the runoff. Several additional ponding tests were performed while the strip seal was at an opening of 1.5 inches, all with success.

Subsequent tests were conducted to simulate thermal contraction of the joint and evaluate the effect on the performance of the bentonite fill. The strip seal gap was widened to 3 inches and several additional ponding tests were conducted, all with success. At this point, the specimen had undergone half a dozen ponding tests and been sitting outside the laboratory for several weeks so that the bentonite was exposed to rain and the elements.

The bentonite appeared to be fully saturated when the strip seal gap was widened to 4.5 inches. The following ponding test failed due to a crevasse that had formed in the bentonite (Figure 62) and the saturated bentonite was unable to expand and seal the opening.

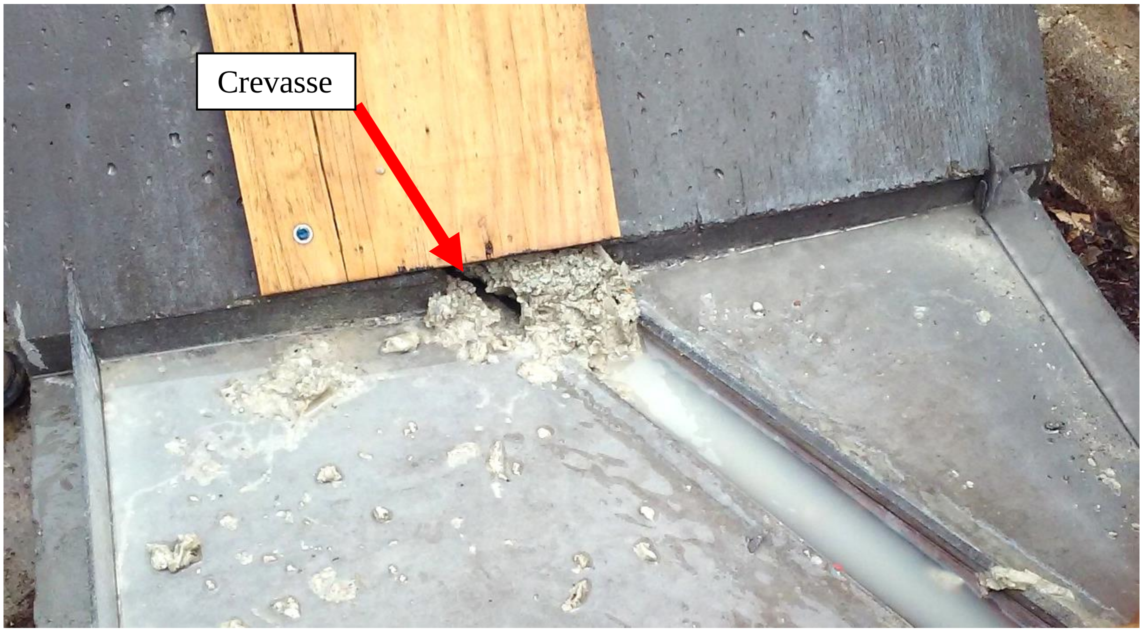


Figure 62. Crevasse that had formed in saturated bentonite causing ponding test failure

The following day, another ponding test was performed, this time with success. The extra time had given the bentonite a chance to dry out and allowed for the bentonite to re-expand and block the flow of water. This demonstration highlighted the ability of the bentonite to re-form to the strip seal gap as it changes in width.

After little to no signs of the bentonite decaying over the span of a month and a dozen ponding tests, the research suggests that the bentonite would require little maintenance in the field assuming proper encapsulation of the area.

One noteworthy item related to the bentonite option is that if any bentonite escapes from the cavity between the cover plate and the joint onto the surface of the deck, the result is a rather slippery surface. Use of this detail may need to be avoided in areas of pedestrian and/or bicycle traffic for safety reasons.

Taking additional measures to ensure the bentonite does not escape containment is recommended before use in the field as well. The plate over the face of the barrier rail used in the laboratory could be extended further, down to the deck, to aid in sealing the bentonite in the barrier rails. Even with this addition, bentonite could still escape under the plate through the strip seal gland, which would be difficult to fully seal because of the joint's inherent movement.

SUMMARY OF RESULTS AND CONCLUSIONS

Past and present experiences with bridge strip seal terminations related to initial construction quality and long-term performance led Iowa DOT engineers to re-evaluate their current termination detail.

Field inspections have found that the poor performance of the current Iowa DOT termination detail often stems from the fact that the blockout region around the strip seal turn-up is not fabricated with the best construction methods and/or quality control practices. Often, a larger than necessary void in the barrier rail is left around and behind the strip seal turn-up during barrier rail construction, and the void is later filled by hand packing concrete into it.

Noting this construction deficiency early on in the research project, the research team sought to re-evaluate the current termination detail as well as test alternate termination details. Constructability, gland installation, and water-tightness were the three criteria established to evaluate and compare the details investigated: current turn-up termination detail (Iowa DOT standard), straight-through termination detail, dogleg termination detail, and bentonite option detail.

Given that the Iowa DOT experiences the most severe problems with the strip seal termination detail on skewed bridges, all laboratory specimens were constructed at a 30 degree skew. This ensured that recommendations for new or improved details were tested under the most critical circumstances.

The construction procedure for each termination detail was evaluated and, once the barrier rail was installed on each specimen, the process of installing and removing the gland was evaluated. This ensured that the glands could be installed and reinstalled without interference from the completed barrier rails, and accounted for the fact that contractors sometimes install the glands before completion of the barrier rails.

Ponding tests were then conducted on each specimen, given it is standard to inspect and evaluate that the joint is sufficiently watertight for all strip seal joints in the field.

The current turn-up termination detail was the most challenging specimen to construct in the laboratory. The detail was difficult to visualize and understand from a set of two-dimensional plans, which added difficulty and confusion to the construction. The research team gained a better understanding of the detail from viewing a 3D model and photos of a strip seal termination provided by the Iowa DOT.

Forming the barrier rail and blockout area around the turn-up portion of the strip seal metal extrusion was difficult because of the complex geometries present; however, proper construction was attained through a basic construction procedure that eliminated the necessity for hand packing of concrete by contractors later. The solution was to use foam to form the blockout around the turn-up.

For evaluation purposes, two different foams were utilized: blue foam insulation board and a spray foam product. In both cases, after the formwork or foam was removed, the resulting finish was desirable and the blockout area allowed for full installation of the gland. The ultimate conclusion was that, if a blockout is to be utilized around the strip seal termination turn-up, forming the blockout with blue foam board is both efficient and results in a quality product. If spray foam is utilized, the face of the metal extrusion should be scraped and scrubbed clean of all spray foam residue prior to casting the barrier rail.

Furthermore, through trial and error, the research team found that the blockout area of the current Iowa detail can be modified so that the blockout is only as wide as the steel extrusions of the strip seal. In fact, the research team found that the smaller blockout area improved installation of the gland because the new surface provided better tool leverages.

This modification simplifies the detail on paper and in construction, while maintaining enough working room to install and remove the gland from the strip seal termination. Redrawing the blockout area and/or noting this on the plans defines the blockout geometry in a more quantifiable way, which may clear up confusion and lead to a more consistent and quality end product.

The deck pour encapsulation method was an alternative construction method that the researchers investigated for the current turn-up detail. This method of construction involves forming and casting part of the concrete barrier rail and blockout region around the strip seal termination (turn-up) simultaneously with the deck pour. The advantage of the deck pour encapsulation method is that, once the strip seal turn-up is encapsulated in concrete with the deck pour, the barrier rail can be cast in one seamless step, whether cast in place or slip formed.

This is a viable alternative; the only notable issue to address during construction is accounting for the head pressure from the encapsulation block on the adjacent deck concrete. Once this issue is addressed, the construction technique produces a quality product that reduces construction difficulties.

The straight-through and dogleg termination details, which both pass through the entire width of the barrier rail and terminate at the exterior edge of the bridge deck, were investigated as termination detail alternatives. These details are similar in that they involve simple geometries between the strip seal, deck, and barrier rail, and are substantially easier to construct than the turn-up detail, regardless of the construction technique (i.e., using blockout techniques or the encapsulation method).

During investigation and design of these details, concerns were expressed related to two key areas: the amount of working room between the barrier rails once fully cast to facilitate installation/repair of the strip seal gland and control of runoff water passing between the barrier rails and off the end of the gland.

The Iowa DOT currently allows contractors to choose between two strip seal manufacturers, D.S. Brown and Watson Bowman Acme, for installation on a new bridge, so those strip seals were the ones evaluated.

For the D.S. Brown strip seal, the gland installation between the barrier rails proved to be simple, taking a total of 10 minutes, and was achieved using a basic pry bar. Both the dogleg and straight-through of the D.S. Brown specimens passed all ponding tests.

The Watson Bowman Acme strip seal was difficult to install between barrier rails, taking the research team approximately 80 minutes to complete. The installation process was cumbersome because of the need for additional working room for the custom installation tool provided by the manufacturer to properly install the gland.

In the laboratory, the Watson Bowman strip seal straight-through detail passed the ponding test, while the Watson Bowman dogleg detail did not. The dogleg detail did not pass any of the ponding tests performed after multiple attempts to install the gland properly. The dogleg bend in the metal extrusion was too sharp for the gland to be properly installed into the extrusion, which caused water to leak through the gland/extrusion/joint.

With a straight-through strip seal joint, the issue arises of water runoff exiting the side of the bridge deck from the strip seal. The main concern here is that chloride-contaminated water runoff from the bridge deck, if not properly channeled away, would trickle down to the substructure and bearings. However, Kansas and Missouri currently use this detail for their strip seal termination and utilize basic water drainage techniques (gutter, tubing, corrugated plastic pipe, drip edge, etc.) to direct runoff safely off the bridge deck and away from the bridge substructure underneath.

Ultimately, laboratory results indicate that the straight-through details, with or without the dogleg, provide exceptional alternatives to the turn-up termination detail. The straight-through option is easily detailed on plans with no loss of clarity, the detail is construction-friendly, and it results in a high-quality, highly effective end product.

The other alternative detail investigated involved a straight-through or dogleg termination design placing granular bentonite in the void between the barrier rails with blocking plates attached to both the front and back faces of the barrier rails. When the bentonite is exposed to moisture or runoff from a rain event, the expansiveness of the bentonite clay blocks the void between the barrier rails and prevents water from draining from the bridge deck.

The bentonite clay proved to work well at creating a watertight seal to the termination area and passed multiple ponding tests. However, repeated ponding tests caused some of the bentonite clay to fall out of containment within the barrier rail void and onto the deck.

This is a potential maintenance concern for two reasons: the amount of bentonite in the void may need to be added to continually and any bentonite that escapes under the blocking plate onto the concrete surface results in a slippery surface. Therefore, use on areas near a sidewalk or with pedestrian/bicycle traffic may need to be avoided. Certain measures can be taken for better containment of the bentonite; however, it is quite difficult to ensure the bentonite would never escape containment.

In conclusion, proper design, construction, and maintenance of bridge expansion joints are important in helping to prevent the deterioration of critical substructure elements. Desirable qualities of a strip seal termination detail provide a seal that is simple and fast to construct, facilitate quick gland removal and installation, and provide a reliable, durable barrier to prevent chloride-contaminated water from reaching the substructure.

Alternate termination details may not only function better than the current Iowa DOT standard, but are also less complicated to construct, facilitating better quality control. However, uncertainties still exist regarding the long-term effects of using straight-through details, with or without the dogleg, that could not be answered in the laboratory in the short time frame of the research project.

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