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Laboratory Investigation of Bridge Strip Seal Joint Termination Details

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Abstract

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 redesign of this detail.

Keywords

Bridge design, Bridge substructures, Chlorides, Deterioration, Expansion joints, Joint sealers, Joint sealing, Joints (Engineering), Runoff, Stripping (Pavements)

Disciplines

Civil Engineering

Comments

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February 2016

RESEARCH PROJECT TITLE

Laboratory Investigation of Bridge Strip Seal Joint Termination Details

SPONSORS

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

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Bridge expansion joints, if not properly designed, constructed, and maintained, often lead to the deterioration of critical substructure elements.

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.

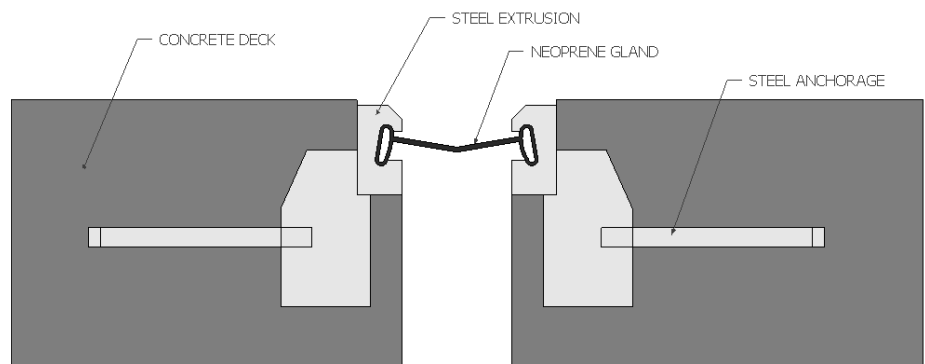
Background

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.



Strip seal cross-section



Field construction of strip seal termination turn-up at barrier rail with blockout

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.

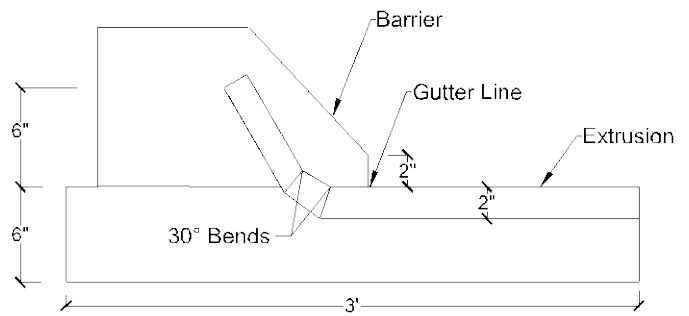
Strip seal termination details vary from state to state. In Iowa, strip seals run transverse to the bridge deck and terminate by turning up and into the barrier rail in a two-step turn. The turn-up prevents water from flowing over top of the strip seal, where it could then reach and cause deterioration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



Section view of turn-up termination detail

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.



Laboratory specimens before testing

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.



Use of a crowbar to install D.S. Brown 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.

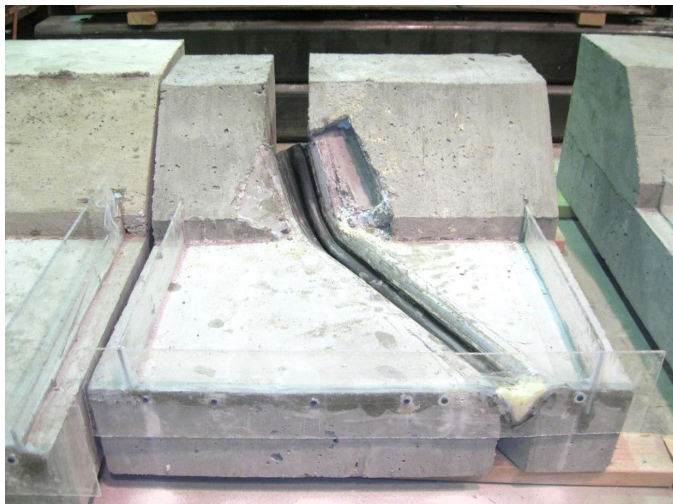
The other alternative detail investigated involved a straight-through or dogleg termination design placing granular bentonite in the void between the barrier rails with blocking plates attached to both the front and back faces of the barrier rails. When the bentonite is exposed to moisture or runoff 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 blackout is to be utilized around the current strip seal termination turn-up, forming the blackout 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.



Turn-up specimen with blackout formed using blue insulation board

- Modifying the current Iowa termination detail so that the blackout 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 blackout area and/or noting this on the plans defines the blackout 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.