Structural Engineering Guidance No. 15-03

Date: November 19, 2015

Distribution: Internal Design Resources

SUBJECT: PRE-RELEASE ON STRIP SEAL AND PREFORMED SILICONE/EPDM SEAL EXPANSION JOINT SYSTEMS USING NEW DESIGN CRITERIA

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EPG Status: TBD

Std. Drawing Status: TBD

Accompanying Documents: Pre-Release (Draft) EPG Articles and QuickSheets for Design at

 <http://sharepoint/systemdelivery/BR/development/Shared%20Task%20Library/New%20Design%20Criteria%20for%20Strip%20and%20Preformed%20Seal%20Design>

Effective Date: Immediately

Expiration/Duration: June 1, 2016 – Up to 6 Months Review Period

Background and Purpose:

While reviewing EPG articles on strip seal expansion joint systems for the purposes of updating and appending new information, design inconsistencies were discovered which led to the manufacturers of strip seal joint systems being contacted for design consultation. What followed from those conversations with manufacturers and of our own accord was that MoDOT sealed joint system (SJS) design could be improved if each manufacturer’s design information unique to their own SJS model were used rather than using standardized design parameters presumed to work for all manufacturers’ SJSs, which is our current practice. Reviewing other State DOTs policies revealed same rationale and that they may have come to same conclusion. (*Note: SJS refers to strip seal and preformed silicone/EPDM expansion joint systems. Preformed compression joint seal system is not included in this discussion but may be in a future guidance.*)

How can SJS design affect long term performance? What is generally known about the in-service performance of strip seal joints (and preformed compression seal joints) is that the state of service is not considered critical and, overall, performance is seen as good. However, service life averages may be less than national survey averages reported in NCHRP Synthesis 319 “*Bridge Deck Joint Performance*”, 2003, and less than manufacturers’ advertised claims. Long term performance of these joint types requires meeting manufacturers’ design information including installation criteria, for example, if to realistically expect that these systems will meet predicted service life, lower maintenance requirements and satisfying total bridge design movement requirements. (*AASHTO LRFD recommends that the service life of just the joint seal material should be 25 years.*)

Therefore, addressing the current design shortcomings could lead to an overall improvement in strip seal joint performance just by focusing on revising current design criteria. Strip seal joint system design guidelines in the EPG have never included installation design criteria or provisions to check potential installation deficiencies in the field to the degree owing to such a critical bridge element which can control the service life and performance outcomes of other major, more critical bridge elements like girder and beam ends, diaphragms, bearings and bent caps. Also, the current racking criterion is generously simple and standard for all manufacturers’ strip seal systems. The benefits associated with improved SJSs performance would seem to exceed associated costs of more thorough design checks.

In order to update the EPG accurately and comprehensively, new SJS design criteria with examples were developed, which could positively affect the installation and service life of these systems.

Lastly, other additions and updates including 5” movement rated strip seal joint systems which have been used on some jobs will be incorporated into the EPG. Introduced earlier, a relatively new SJS to MoDOT called a “preformed silicone/EPDM seal joint”, which also has been used on several jobs, will be incorporated into the EPG with guidance. New design criteria applies equally to this joint based on same reasoning.

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Because of the design changes involved and the fact that the Development Section wants gage outcomes, evaluate, and adjust, a “Pre-Release” showing proposed revisions to the EPG and introducing new SJS design criteria seemed appropriate. Therefore, this Pre-Release is for internal design review only. It is a trial implementation when users should review and make comments before a final release. Also, there are other proposed SJS detailing changes that are being released in a supplemental Structural Engineering Guidance 15-04 for review by Grades 17 and above before concluding detailing development work on SJSs.

GUIDANCE: Instructions and Features of New Design Criteria and Other

**Instructions:**

Perform SJS design using new design criteria and integrate into normal sealed joint expansion system design for the purpose of comparing the Pre-Release guidelines and design examples with current EPG requirements and practice, and report final design results to the Development Section for tracking. In fact, report any limitations, conflicts or shortcomings of the new criteria and design examples, or any improvements, including QuickSheets (provided with this guidance) enhancements, to the Development Section.

*Do not use new SJS design results pending final release. Pre-Release does not supplant current state of practice. The Pre-Release is an opportunity to review and compare design results; in the interest of using an improved design, or in the case of a conflict with current practice, however, new design results can be used if it meets certain conditions, see the Development Section, in which case this Pre-Release should be documented in the final design computations for the seal joint system design noting SEG 15-03.*

For preformed silicone/EPDM seal joint systems, forward nontypical armor or nonarmor installation details to Development Section so that the Standard Drawings can be expanded to show optional details. Also, nontypical strip seal expansion joint systems details can be forwarded to the Development Section for the same purpose. Also, remember that any special detail can be added to the Bridge Special Details, which is an e-storage location, for easy future reference for duplication or guidance.

**Features of New Design Criteria and Other:**

*Major Feature*

1. For every bridge job that requires an SJS, all qualified manufacturer’s seal joint system models will be checked for acceptance. This means that either a 3”, 4” or 5” movement rated SJS, or a combination of them, produced by a single or multiple manufacturers could be found to work for a bridge job that may only have a 3” movement requirement, as an example, but installation, racking and total movements are satisfied at all possible temperatures. Current practice is generic (or nonspecific) by comparison where, continuing with our example, only a 3” movement rated SJS produced by any manufacturer will be found to work for the same bridge job, but installation and racking are not checked at all possible temperatures and not based on actual manufacturers’ limits. (*Using the new criteria, the 3” movement rated joint seal may not work, and either a 4” or 5”, or both a 4” and 5”, joint seal may work.*)
2. Qualified SJSs are MoDOT time-tested or adopted systems that are permitted for use on MoDOT bridges. Accepted SJS models are those models that specifically meet the characteristic gap opening design checks for a MoDOT bridge job and which will be reported on the plans.
3. There are only two manufacturers of strip seal expansion joint systems and three manufacturers of preformed silicone/EPDM seal expansion joint systems. Each manufacturer may have 2 to 5 different models for each SJS, but only some models are qualified and will be listed in the Pre-Release. It is not difficult to check all of them using a spreadsheet which is required since multiple models may work for a bridge job.

**SJS Manufacturers and Qualified SJSs**

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| --- | --- | --- |
| Manufacturer / Seal Joint System Type, Model Name and Material | **Strip Seal (Armored)** | **Preformed Silicone/EPDM Seal (Adhesive) (Armored and Nonarmored)** |
| DS Brown | Steelflex® SSPA | Neoprene | V-Seal® | EPDM |
| Watson-Bowman-Acme (WABO) | Wabo®StripSeal | Neoprene | Wabo®SPS | Silicone |
| RJ Watson | *No Equivalent Product* | Silicoflex® | Silicone |

*Neoprene is synthetic rubber; EPDM is Ethylene Propylene Diene Monomer which is also a synthetic rubber.*

*Discovery -*

1. After many discussions with SJS Manufacturers about their systems and models, the undeniable conclusion is that current practice generalizes some important design checks or is missing some altogether; for example, strip seal installation design checks for skewed structures should require checking gap openings at adjusted setting temperatures (*those other than MoDOT standard 60º setting temperature*) can produce ineffectual design racking greater than elastomeric seal limits. It was also discovered that not all manufacturer’s SJSs have same limits on maximum closure and racking limits which can produce faulty maximum opening limits. Further, not all manufacturers give racking criteria except to report that their models are good for skewed joints. We had to ask for this information. Lastly, manufacturers revealed that they backcheck our work based on plan details, but it was not found compelling or a relief in that if our plans did show an incorrect design, a manufacturer would provide an important backup role and make a correction which to our knowledge has never happened and yet using the new criteria it can be shown that current criteria can produce bad results. It should be mentioned that this is not a contractual role on the part of the manufacturer since SJS design has always been the responsibility of MoDOT. *Bottom line: we will continue to design our own joint seals.*

*Specifically -*

1. In order to design check a manufacturer’s model, their exact criteria should be used. All SJS models by all manufacturers for a particular type of SJS should be checked. Some examples:
* Strip seal expansion joint system:

DS Brown and Watson-Bowman-Acme have different racking (movement parallel to joint) limits, and movement (maximum opening parallel to RDWY) limits. Based on these manufacturers’ racking and movement criteria, a design check for a squared bridge may show that two manufacturers’ models are accepted. For a skewed bridge, a design check may show that only one manufacturer’s model is accepted; however another manufacturer’s model may also be shown to be accepted using a larger joint seal size if it meets the design requirements. Both are accepted to use in this case, in fact any joint seal is accepted if it meets all of the design check requirements for installation, skew (racking) and total movement (max. gap minus min. gap). For the case of a 5” movement rated model, which can allow up to 5” gap parallel to roadway, it may work for 4” gap parallel to roadway or less in which case it would be considered accepted for use. SPM or SLE approval will be required to allow greater than 4” gap parallel to roadway which will mean generally that a 5” movement rated strip seal model will be required by design. Seemingly, this does put a 5” movement rated strip seal in a category other than case-by-case approval as is the current practice. Skews up to 55º and smaller horizontal curvature structures are allowed by design.

* Preformed silicone/EPDM expansion joint system for skews up to 45º by design:

DS Brown, Watson-Bowman-Acme and RJ Watson have different racking (movement parallel to joint) limits. Since installation width is larger for larger joint seal, considering a larger seal may not solve a design installation issue. Based on manufacturers’ racking and movement criteria, design check may only show one or two accepted manufacturer products for skewed bridge. **SPM or SLE approval will be required to allow greater than 4” gap parallel to roadway.**

*More Specifically -*

1. More comprehensive checks are necessary satisfying gap openings across required temperature ranges for installation, and all possible temperatures for racking and total movement. A large part of these Pre-Release design criteria is focused on design performance of a joint seal at many temperature checkpoints. Criteria concentrate on meeting manufacturers’ design information at these temperature checkpoints.

To profile the seal over the predictable service temperature range for which it is to perform is desirable. Extending service life is an improvement. Considering installation criteria and restricting racking limits based on more critical design are seen as an area than can be improved. Since warranties do not extend past job acceptance in the field, getting it right and design checking each SJS individually is important.

Due to stricter design criteria that considers installation and skewed effects, maximum possible expansion lengths may be less than current practice for skewed structures. They may be greater for squared structures. However, estimated bridge movement is conservatively estimated in accordance with AASHTO LRFD. At best, it may be more representative of actual bridge movement due to heavy use of elastomeric bearing pads and the fact that elastomeric pads do not get stiffer with time, and deteriorated pads generally restrict movement less, or lock up, like frozen rusted steel rockers or expansion steel bearings generally. Keep in mind that the coefficient of expansion used for both steel and concrete is an average, more like a median value. All of this could lead to discretionary use of the LRFD load factor for thermal movements of 1.20, for example to use wholly, partially or not at all. Consider that the 1.20 load factor for new bridge is for unknowns and using a 1.0 load factor for existing bridge may be possible where movements have a recorded history and are known with some accuracy. Consider a 1.0 load factor for new bridge and existing bridge installation gap (opening) computations since the setting gap is fixed.

Minimum opening of expansion gaps will be different for different types of SJS. Tighter restrictions are imposed on minimum openings than manufacturers. For example, the quarter inch extensions at the top of each strip seal armor extrusion are the points at which a minimum factored opening (a.k.a. maximum closure) is measured at ½”. (*Manufacturers allow the joint to fully close*). This is to protect and secure the lug (ear) of the gland and to provide room for the seal to fold especially when the gland is carrying debris. It could also be considered to protect the seal against snowplows. Though crushable under maximum expansion, destroying this part of the armor could be serious and therefore is not allowed. It would complicate, at worst prevent removal and reinstallation of a future joint seal (gland) which is not part of good design. There have not been incidences of this reported to this office so it is anticipatory design practice rather than correcting a problem at this point.

*(Tables of manufacturers’ SJS design information that will be included in the final release of EPG will be updated for manufacturers’ changes in design information.)*

*What about using a 5” movement rated SJS?*

1. Using a 5” movement rated SJS requires approval of SPM or SLE as is current practice and will be same using new design criteria. The exception to current practice is that it is not the 5” movement rating SJS that requires approval but any joint opening that exceeds the AASHTO LRFD maximum limit of 4” parallel to the roadway.

*What about joint seal width preferences?*

1. It has been the case that a larger joint seal provides a larger capacity for debris loading and probable eventual puncture of the seal due to increased vehicle wheel pressure on same, however a large joint seal in a smaller joint opening won’t experience the increased vehicle wheel pressure and most likely will assist in shedding racking stresses, or if squared, avoid large tensile loading. It follows that if a larger joint seal is accepted by design as an alternate to a smaller joint seal, it should be allowed on the plans since it may have less risk of puncture, less racking load and less risk for pullout than a large joint seal for a large opening.

*Current Practice and Comparison –*

1. Current practice is to design check a single generic strip seal joint width (or preformed silicone/EPDM seal width) and if accepted, then report it on the plans. It is a generalized design check meaning that installation and racking are assigned a constant value to represent all manufacturers’ models neatly lumped into either a 3” or 4” or 5” nominal joint seal width category. The idea of reporting a joint seal width infers that the total movement or the maximum extensibility required is the same as the joint seal width shown, which it may not. Manufacturers do not correlate their system model to joint seal width, at least not in their published design information. Previously designed systems could fail new design criteria which are a good reason that specifying a manufacturer’s model rather than a generic joint seal width makes more sense. (Using only our simplified design table may not be conservative. Individual calculation checks for specific models will allow all conditions to be expressed.) Other problems with current practice are:

Problem 1: Joint seal width is given on plans. Manufacturers do not report joint seal (gland) sizes in their design information for models.

Problem 2: Gap at 60º is always the same @ 2” on the plans. It may need to be different to accommodate minimum installation opening requirements.

Problem 3: Minimum joint width is given as 1”. It does not state if this is at the top of roadway surface between ¼” extrusion tabs or at lower point on extrusion (*AASHTO LRFD requires 1” for steel structures only because concrete structures can undergo creep and shrinkage*).

Problem 4: Showing a single joint seal width without having design checked each manufacturer’s design information presumes that all manufacturers’ models that use that nominal joint seal width are accepted which is clearly not the case or good practice. This is “canned” design when it should be specific product design. For skewed joints, there is a real concern where manufacturers can have very different design information. (*Neither movement nor minimum joint openings are given on plans now which can make back checking our design difficult for manufacturers.*)

*Major Feature*

1. For every bridge job that requires an SJS, all accepted SJS models by design will be reported on the plans in a table identifying manufacturer, system and model number. It is important to note that accepted SJSs are those that meet both MoDOT design conditions specific to a bridge job and as many manufacturers’ design information specific to a SJS. All three manufacturers were asked about this practice of specifically reporting manufacturer type and model and all concurred that it was acceptable.

Manufacturer’s type and model are recommended to be reported on the plans, meaning that if multiple manufacturers and models work for a given type, even if multiple models for a single manufacturer work, all possible accepted manufacturer model combinations are reported.

Pat Martens, former District Bridge Engineer writes that “There also needs to be a better definition given to the expansion device types within TMS and an effort to include the manufacturer’s trade names so that we have a better way to identify and track the various systems out there. There is already a means to record expansion gaps for various temperatures. This is another good tool to use in determining the type system which might be appropriate to use.” Written about poured silicone expansion joint seals, it applies equally to any installed proprietary sealed systems like strip seals and preformed silicone/EPDM expansion joint systems.

*Other Features*

1. Recommended use of Preformed Silicone/EPDM Seal Joint System is included in this Pre-Release for incorporation into the EPG. This SJS is permitted for use on bridge rehabilitation jobs only, not including re-decks. It may be used with or without steel armor. Design shall follow new design criteria established for all SJSs. A new standard drawing will be provided.
2. Up to a 5” movement rated strip seal is allowed by current practice with SPM/SLE approval on a case by case basis. This practice is incorporated in this Pre-Release. Correspondingly, up to a 5” movement rated preformed silicone/EPDM seal joint system is incorporated in the Pre-Release as part of introducing these types of SJSs.
3. Links to SJS standard drawings will be provided in the EPG, except for special details considered unique and not shown on the standard drawings which will remain in the EPG.
4. Strip seal expansion joint systems, when designed using new criteria, can perform for skewed bridges up to 55º and smaller horizontally curved structures (*current practice is tangent with maximum 45º skews*). Preformed silicone/EPDM expansion joint systems may be used accordingly. Both systems will reach allowable application limits as controlled by load-factored design limits and material (*or system*) limits given by following each manufacturer’s design information.
5. Example drawings showing expansion direction guidance, both longitudinal and racking, for curved structures are included (*reprinted from “Source: FDOT”*) and allowed for designing SJSs.
6. Manufacturer’s SJS design information for strip seals joints and preformed silicone/EPDM seal joint systems are given in the Pre-Release EPG articles.
7. A table showing required gap openings for accepted temperature adjustments in the field in 10º increments will now be provided for installations replacing a note. The installation temperature range will have been checked using the new design criteria.

1. Using a thermal load factor of 1.0 (not 1.20) for new bridge and existing bridge installation gap (opening) criteria is preferred since the setting temperature is controlled.
2. Separate QuickSheets (spreadsheets) for strip seal and preformed silicone/EPDM seal joint system designs are available for use and will be located at SharePoint/Bridge/Development Section/QuickSheets. QuickSheet is concept proofed but unchecked.

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(Question) *How are strip seal joint systems performing now on MoDOT bridges?*

Within MoDOT, it is fact that overall strip seal joint systems perform well, and that there are occasional failures where they pull out and the design life may fall short of the commercially advertised life by manufactures or what other states are experiencing. NCHRP 319 recognized that the advertised service life is possible. To this effort, increasing assurances by properly designed seal joints seems a reasonable proposition to undertake to maximize the benefit of these seals. (Preformed silicone/EPDM seals are new and do not have a MoDOT history.)

(Question) *Is there a concern about in-service sealed joint designs and moving forward still using existing sealed joint design criteria in the interim until final release of new design criteria to the EPG?*

Yes there is concern which is the reason for this Pre-Release for review. What was designed and installed in the past works. What is designed to be installed using the current criteria will work. What will be designed to be installed using the new criteria will work better. Our current designs follow AASHTO LRFD which provides assurances that marginal designs will still function, i.e. uniform temperature load factor. However, when a comparative design is performed, it can be shown that strip seal designs using the current criteria may be under matched when put to the test of a more rigorous design criteria. For now, until adoption of new practice, it just means having a lesser factor of safety under certain circumstances.

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### RESEARCH IN PROGRESS (Federal and State):

NCHRP 12-100 [Active]**:** *Guidelines for Maintaining Small Movement Bridge Expansion Joints* by University of Delaware initiated in July 2014 and extending for two years. Installation concerns specific to small movement expansion joints are being investigated in a new NCHRP synthesis report in which this item is examined along with other design parameters in relation to extending the service life of these types of joints.

MoDOT TR201506: *Evaluation of Finger Plate and Flat Plate Connection Design* by University of Missouri-Columbia/HDR Engineering initiated in October 2014 and extending for two years. The objective of this project is to learn the cause of why some MoDOT finger plate and flat plate expansion devices prematurely fail/deteriorate with emphasis on a pre-notion that high traffic volumes may play a significant role. Then use the resulting information of what is learned to design new LRFD finger plate and flat plate standard designs that will last 40 years or more with minimal maintenance. New EPG articles on finger plates and flat plates, new design methodology and standard drawings are expected outcomes of this research. Immediate implementation is likely.

MoDOT Bridge Division has initiated product evaluations of a preformed silicone/EPDM expansion joint seals each produced by DS Brown, Watson-Bowman-Acme and RJ Watson. These evaluations will be performed by MoDOT Central Office Materials Laboratory. They began in the Fall and look at several characteristic features and manufacturers’ claims of performance including UV testing, tension testing, racking testing, water tightness testing, pullout testing and splice testing. Results of these evaluations will be used in conjunction with information in this Pre-Release, and its results, in revising guidelines.

### References for SEG 15-03:

NCHRP Synthesis 319 Bridge Deck Joint Performance

Emails and discussions with Pat Martens

AASHTO LRFD Bridge Design Specifications

“[Joint Sealing Systems in Missouri](file:///%5C%5Cghdata03%5Cghq_brustation_pw%5Cbr-proj%5CA_Devlopment%5CWeb%20Page%20Files%5CDevelopment%20Reading%20Room_files%5CExpansion%20Devices%5CJoint%20Sealing%20Systems%20in%20Missouri.docx)”, MoDOT Bridge Div. /Bridge Maintenance, Pat Martens, 2011

Manufacturers, DS Brown, Watson-Bowman-Acme and RJ Watson

Other State DOTs design manuals, examples, standard drawings

Suggestions, recommendations or commentary concerning this guidance should be directed to the Development Section for review and updating the Engineering Policy Guide.