Structural Engineering Guidance No. 18-01

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Distribution: All Engineering Resources

SUBJECT: NEW FINGER PLATE AND FLAT PLATE EXPANSION DEVICES DESIGN

IMPLEMENTATION

Contact: Gregory Sanders/Suresh Patel

EPG Status: To Be Submitted

Std. Drawing Status: In Work

Effective Date: Immediately For Jobs to Be Designed (See Development Section)

Expiration/Duration: Active until Incorporated into EPG and Bridge Standard Drawings

**C O N T E N T S:**

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Expansion Device for Developing Standards

1. New Research and Background:

New research that addresses the evaluation of finger plate and flat plate connection designs was concluded recently by the University of Missouri-Columbia and HDR Engineering, initiated at the request and lead of MoDOT Bridge Division, and a final report prepared for the Missouri Department of Transportation, Construction and Materials Division.

Results of experimental live load static and dynamic testing performed in the field on two in-service finger and flat plate expansion devices were used in building and calibrating a finite element analysis model (FEM) of same. Parametric FEM analyses and engineering static analysis including AASHTO LRFD code design computation checks were then used to develop finger plate hardware. All of this led to a proposed implementation plan in the research where expansion need is first matched to an appropriately predetermined level of a finger plate expansion solution for new expansion structures or replacement installs needing large movement expansion devices. A retrofit solution was also made part of the research requirement. These solutions are as follows:

1. A new robust finger plate expansion device design (*designated as* ***Type B***),

2. A lesser robust, enhanced MoDOT finger plate expansion device design

(*designated as* ***Type A***)

3. A repair and retrofit design solution for converting failing, in-service, welded finger plate

connections to improved bolted connections for increased structural and fatigue strength, and

extended service life.

The implementation criteria as proposed in the research for where Type A and Type B devices are recommended are based on traffic counts, roadway classification and bridge classification. These are the expansion needs mentioned earlier. For example, heavily traveled bridges or Major Road bridges or Major bridges should use Type B, all others could use Type A.

The research “*Evaluation of Finger Plate and Flat Plate Connection Design*”, Project TR201506, Report cmr16-008, January 2016, can be found on line at the **SP: Development: ReadingRoom** or at:

[http://sharepoint/systemdelivery/BR/development/Reading%20Room/Expansion%20Devices/2016%20Evaluation%20of%20Finger%20Plate%20and%20Flat%20Plate%20Connection%20Design%20MoDOT%20MU%20HDR.pdf](http://sp/sites/br/development/Reading%20Room/Expansion%20Devices/2016%20Evaluation%20of%20Finger%20Plate%20and%20Flat%20Plate%20Connection%20Design%20MoDOT%20MU%20HDR.pdf)

It is also available on line at MoDOT’s Innovation Library:

<http://www.modot.org/services/OR/byDate.htm>

For many years, some finger plate expansion devices have failed inexplicably before reaching a service life commensurate with the high cost and labor involved with installing and maintaining these systems. Some flat plate expansion devices have also failed before reaching an acceptable service life. Conjecture on why some finger plates have failed or performed poorly while mostly others still perform as expected is wide and diverse and any one theory not any less plausible than the next. Flat plate expansion device failures have the distinction that their poor performance may be more easily detected both audibly and visually due to a slapping flat plate where a gap has developed between the plate and its support. Failed finger plate expansion devices can also make loud noises too but the root cause of failure may not be as easily detected. Failures of each type can generate large costs and hugely inconvenient traffic disruptions in either repairing or replacing them.

Therefore in late 2014, it was decided to issue a request for proposals to the research community for interest in investigating the causes of prematurely failing finger plate and flat plate expansion devices installed on Missouri State bridges. The research, it was determined, had to investigate finger plate failures under presumed and believed largely to blame high traffic counts. It also had to develop new finger and flat plate expansion device designs that would at least be as durable as the life of the deck estimated at 40 years. And lastly, it had to develop standardized device designs for typical ranges of movements seen by regular bridges.

Installation practice presumably has improved over the years and also some hardware features have been changed that may have helped these devices to endure longer including using straps/bars in lieu of rebar, using longer welded studs, adding air vent holes and requiring that concrete be consolidated behind and under the steel plates. In this latest research, while poor installation practice is not ruled out as a cause, it is not believed to be the only cause leading to failures. This prompted a heightened look into improved structural engineering features and strength resistances of any new design.

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1. Principal Research Results:

PROPOSED FINGER PLATE EXPANSION DEVICE DESIGNS (*and recommendations for use*)

***Type A – Proposed Standard Modified MoDOT Finger Plate Exp. Device for Regular Bridges***

1. Modifies MoDOT’s current standardized 4 1/2”-6 1/2” movement finger plate device
2. Designed for regular bridge movements; Less conservative for larger movements
3. Designed using AASHTO LRFD, fatigue resistant with 100% impact
4. 10’-6” max girder spacing
5. Designed for movements between 4” and 8 ½” and skews ≤ 60°
6. Bolted-down, removable finger plate replaces welded finger plate
7. Thicker finger plate 1 ¾” replaces 1 ¼” plate (*because recessed bolt holes require increased thickness*) which maintains 4” varying width fingers
8. Larger support beam W18x130 replaces W14x43 (*triple the original weight*)
9. Adds web stiffeners spaced at 12” from 3’-0” (*triple the stiffeners*)
10. Adds lateral and vertical and more rotational positioning adjustability via threaded support rods at the saddle which results in an increased steel girder web coping requirement
11. New ½” bent plate replaces C-channel connector with horizontal and vertical adjustability
12. Includes details for adding a drain trough
13. Recommends closure pours
14. Recommends a more workable concrete for improved consolidation
15. Recommends construction installation sequencing instructions (*requested by MoDOT*)
16. Recommends construction inspection recommended
17. Increased cost expected per foot over current design to fabricate
18. Increased cost expected per foot over current design to install

***Type B – Proposed Standard Robust Finger Plate Exp. Device for Approved Bridges\****

1. New design that can handle more movement, much larger, more robust and more expensive
2. Designed for very large bridge movements; Ultra-conservative for regular bridge movements
3. Designed using AASHTO LRFD designed, fatigue resistant with 100% impact
4. Designed for movements between 4” and 16” and skews ≤ 60° (≤ 20° for prestressed girders), finger plate device <= 189 feet long (transverse thermal expansion limit)
5. Bolted-down, removable finger plate
6. Plate thickness can vary based on movement with 2” width straight fingers
7. Thicker plates are required due to recessed bolt holes in finger plates
8. Straight fingers are preferred since thicker plates are required, better for motorcycles
9. Includes two support W-beams each side which adds structural redundancy, i.e. less reliance on concrete support (*current design uses one beam per side*)
10. Increased anchorage strength, i.e. bigger anchor plates and increased number of studs
11. Includes details for adding a drain trough
12. Recommends closure pours
13. Recommends a more workable concrete for improved consolidation
14. Includes construction installation sequencing instructions (*requested by MoDOT*)
15. Improved construction inspection recommended
16. More than triple the cost per foot expected above current design to fabricate and install

\* Approved bridges means bridges with high traffic counts/truck counts, Major River and Lake

Bridges, major bridges with large movements, discretion of SPM, SLE and approval of the

Assistant State Bridge Engineer.

*Note: The main failure mechanism of current design determined from research was related to*

*weld fatigue. Utilizing bolts in place of welds eliminates this risk.*

PROPOSED FLAT PLATE EXPANSION DEVICE DESIGN

1. Modifies MoDOT’s current standardized 4” movement flat plate device
2. Widens flat plate
3. Widens support plate
4. 1/3 more welded studs
5. Adds more positioning adjustability
6. Includes details for adding a drain trough
7. Recommends closure pours

PROPOSED RETROFIT FINGER PLATE EXPANSION DEVICE DESIGN

1. Modifies failing in-service welded finger plate expansion device systems
2. Adds bolts to field-drilled holes through finger plate and front of support beam flange
3. Adds web stiffeners
4. Adds plug welds to field-drilled holes through finger plate at rear of support beam flange (*as nec.*)
5. IMPLEMENTATION Planning, Instructions and Guidance:

|  |  |  |  |
| --- | --- | --- | --- |
| **Implement, Yes or No** | **Proposed** | | **Proposed Retrofit Modifications** |
| Finger Plate | Type A - Yes | Type B - No | In Field Trial |
| Flat Plate | Yes | |  |
| *Note:*  *Office development and design practice will focus on the “less robust” design (Type A) because it is recognizably more robust than its predecessor, costs less than Type B and the details can be standardized readily.*  *Both types of proposed new and modified finger plate designs are designed for fatigue and high impact. The Type B “robust” design would seem to be more durable, hence provide the greatest resistance to live load, impact and fatigue, and theoretically, a longer service performance life. However, it is costly to put into routine practice and the details are not nearly in final form as those of Type A.* | | | |

1. Proposed **Type A** Finger Plate expansion device will be implemented at this time for all jobs. See Development Section for details until new standard drawings are released.
2. Proposed **Type B** Finger Plate expansion device will not be implemented at this time. Producing standard drawings will take the effort of both the Development Section and a design team(s) working cooperatively to generate final job drawings and guidance. **Type B** details will be available for preliminary review should a job be approved for its use. Therefore, see Development Section for **Type B** unchecked working (*research*) drawings. *Our goal should be to not let these details go stale.*

When could Type B finger plate be considered?

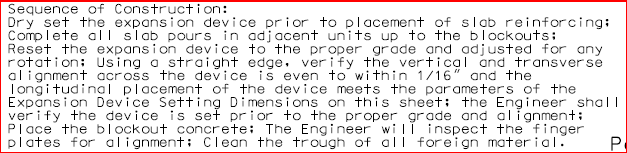
*Very high traffic volumes, Major River, major road bridges, high truck volumes, large skews or unanticipated bridge movement potentials, and with ASBE, SPM or SLE approval. The research study proposed that the robust finger plate design should be used in locations with a Passenger Car Equivalent (PCE) of 20,000 vehicles per day or greater with an average PCE factor (Truck/Car ratio) for Missouri of 2.0.*

*(Note: KDOT’s fingerplate design which was one of two archetype finger plate devices cited positively in the research report could be considered as a precursor to Type B and could be produced and installed at less cost than Type B.)*

1. Proposed Flat Plate expansion device will be implemented at this time. See Development Section for details until new standard drawings are released. (*Usage of these devices will be limited in favor of using our preferred strip seal expansion systems which are considered equally acceptable for skewed and curved new bridges for the same movement.*)
2. Retrofit finger plate expansion device modifications are pending based on results of an on-going field trial of an actual failing finger plate device repair at this time. Early indicators are that field drilling holes through 1 ¼” finger plate is difficult. Field drilling recessed holes in 1 ¼” plate is more difficult. Retrofit design procedure and details, or best practice guidance, will be provided upon successful field trial and if approved for implementation.

GUIDANCE with Recommendations and Obstacles to Implementation: (*In no particular order)*

1. Drain troughs with connection details will be shown on all new Type A finger plate and flat plate standard drawings, either within the borders or given independently outside the borders. Use of drain troughs for finger plate and flat plat expansion devices is undecided at this point as a matter of policy. In any event, the following list provides direction and concerns if using troughs and should be considered for making policy. It is based on experience, engineering judgment, practical maintenance and the following report “Steinberg, E., Walsh K., Sparks N., *Bridge Trough Maintenance Evaluation on Finger Joint Bridges*, Ohio University, Ohio Dept. of Transportation, 2016”. (*In no particular order.*)
2. Recommend that if a drain slope of 10 percent (1.25 in/ft.) or greater can be maintained across the trough, permissible use is automatic; otherwise approval of the Assistant State Bridge Engineer would be required. Finally, slopes less than 8 percent should not be allowed and only flexible drain troughs used (Bridge Memo, Oct. 12, 2001).
   * + 1. Any drainage collection provision is an improvement over none if the collection and disposing of the drainage can be designed and maintained properly to run effectively.
       2. Give drain slopes on a layout of drain troughs on drawings. Space on sheets has been provided for this.
       3. Standard conceptual drawings of possible drain trough layouts can be made available as part of the standard drawing guidance or in the EPG. Layouts should consider regular and wide bridges, single sloped drains from end-to-end versus sloping from the interior, staged jobs, drainage at overhangs only if draining from interior is not possible.
       4. Provide as much slope as possible for flow, moving drainage and debris and cleaning. For wide bridges, the high point could be at the centerline of the bridge to drain to each side if
3. Drain ends should be open-ended and terminated at 6” – 18” past the edge of the deck in order to gravity-drop drainage to a stabilized, erodible-resistant, ground deposit like concrete slope protection, rock blanket or rock stabilized landing. See IDOT detail (Steinberg et al., 2016).
4. Consider using troughs with flat plate expansion devices when there may be problems with drain-through like bridges over parking areas, viaducts over low occupied grounds, railroads. (*see item e*)
5. Consideration could be given to the fact that small sections of bolted finger plate can be made removable in the shoulder area for (or to assist with) trough cleanout.
6. Always use troughs on upper decks of double-decked bridges.
7. Implement trough maintenance policy, developing cleaning schedules and routine inspections to “keep the debris load down” and leaks in check. Use of pressurized water, compressed air, vacuum, other special tools, or a combination should be recommended in EPG under bridge maintenance. Keep it simple and fast and it likely can get done.
8. In lieu of troughs, a rough drainage control design feature could consider removable fabric flap design with bent steel plate shields, or just metal deflector shields.
9. On design exceptions: Write guidance loosely so that design exceptions can be avoided.
10. On pay item for drain trough: To be discussed as to whether it becomes an independent pay item.
11. A fabric trough specification will need to be developed if adopted for use, or as an example, *see KDOT specification attached,* ***Appendix D***.
12. Based on KDOT details, if a fabric trough requires a splice, lap and bond downslope or at center line. Add an additional layer of fabric (in 6” to 12” strips) to the outside of the trough at girder locations were rubbing can occur. Also, add an additional strip on the outside near the discharge end to stiffen and maintain its shape due to wind and wind gusts due to trucks.
13. This latest research study asserts that by requiring closure pours, CM Division is in a better position to control the final concrete placement; better position to control the final positioning of the device. It is to the advantage of the Department at this juncture to ensure the structural soundness of the supporting concrete for the modified finger plate (Type A) designs which the study shows that when in a compromised condition, the supporting concrete could be a major contributor to the observable weld failures of past deteriorated expansion finger plate device installs.
14. In tandem with requiring closure pours, hand packing concrete around these types of expansion devices could be introduced and made required in addition to vibration. All that is required currently is vibration (*deterioration of concrete adjacent to device is reported as No. 2 reason for failure for finger plates from survey, No. 1 for flat plates; damage from snow plows next highest reported for both*). It is AASHTO recommended.
15. At this time it would be important to recognize that the minimum time of bridge deck cure before traffic loading is 10 days FROM last closure pour. No exceptions.
16. At this time it would be important to recognize that any VE proposals to eliminate closure pours be categorically denied.
17. At this time it would be important to recognize that vibratory screeds or portable finishing equipment or hand trowelling may be requested by the contractor for finishing closure pours. Closure pours should be treated the same as any other slab pouring sequence and normal finishing operations maintained throughout. Therefore, it should not be allowed.
18. At this time it would be important to recognize that contractors could propose using an altered skip-pour slab pouring sequence in lieu of expansion joint closure pours if expansion joint is at an intermediate bent. Therefore, it should not be allowed.
19. Depressing finger plate joints ¼” to mitigate effects of snowplow impacts should be considered. This was cited in the research as a major reason for finger and flat plate failures. Current design requires that fingers are ground or bent down last 3”. This will not change with new Type A*. (Note: Depressing strip seal joints have also been requested for review on an unrelated Development Section project.)*
20. Informational announcements should be issued to our finger plate device fabricators and AGC. There are new details and construction installation instructions with inspection requirements on the plans; increased CM Division inspection and hold points will be the new normal. With current QC/QA responsibilities, it is not sure how this will be received.
21. Increased fabrication and construction costs should be reviewed and used for new Type A finger plate device complete in place. Fabrication is different with (*welding is eliminated however*), construction hold points and inspection are new, closure pours and hand packing are new, and field positional adjustments are more complicated than in past. Time is critical for installation because of temperature-sensitive adjustments and concrete pours.
22. On wider bridges, and maybe on normal width bridges, strategically located splices in a finger plate should be considered based on future removal of plates for maintenance (trough cleanout aid), and limiting weight and unwieldiness of the finger plate itself, and also for construction staging purposes; untorqueing fully torqued high strength bolts may be a challenge for reusing nuts and aligning plate holes with support holes (thermal expansion issues and heat of the day). Can A325 nuts that are fully welded to the bottom side of the finger plate be relied upon and reused? Same goes for new flat plate devices.
23. Full height steel curb plates are recommended for expansion openings greater than 5”. These are not currently used for movements up to our standard finger plate movement of 6 ½” (equivalent to 3 ¼” + 1 ½” + ½” = 5 ¼” opening). These would be required for Type A (and Type B when adopted). Details of full height barrier plates will be given in the margins of the standard drawings with guidance (see IDOT barrier plate details for recommended adoption).
24. Another option is to add a third level of finger plate device design when our current design could be utilized for very low traffic counts essentially outlaying a tiered approach to identifying which finger plate device type should be used as in from “robust” to “least robust”, *Type B to Type A to Current Design*. Keep in mind that on average nationally, only 12% fail based on the research report which considered MoDOT’s current design. However, the increased cost of using the modified Type A design over the current design may be negligible; therefore, use the modified design Type A with less risk of failure. The increased cost of using the proposed Type B in lieu of the modified Type A is much greater and more difficult to justify on standard/regular bridges with movements up to 8 ½” which is the maximum movement for Type A. Greater movement would need to be accommodated by Type B or designed specifically.
25. Thickness of current non-integral abutment backwall is insufficient according to the research. Type A hardware requires a thicker wall or alternative engineering design of the hardware at the backwall. Type B requires the same consideration. The modified flat plate is also the same. This leads to Item No. 10. Development Section will work with design teams. For example, backwall thickness required would be 18”, whereas currently it is 12”, however it is not typically the hardware or concrete that fails at the backwall and it may not be necessary to use a thicker backwall.
26. As an alternate, expansion devices could be moved to an intermediate bent which brings up Item No. 11. But first, the fact that we don’t have a policy of when and if expansion should be moved to an intermediate bent is an issue with the associated concern that any device placed at an intermediate bent should account for potential abutment movements as well.
27. Intermediate bent caps will need to be widened to accommodate wider diaphragms for Types A and B and also for modified flat plates.
28. Construction Installation Sequencing should be made part of the plans (or BSPs) to insure the level of performance determined probable from the research. Findings of the research study and our own investigative efforts support that and in order to prevent failures, it is in the Department’s best interest to require and insure that these devices be installed correctly. Requiring contractors to follow given construction step for installing all finger and flat plate expansion devices with hold points for MoDOT approvals seems justified because MoDOT got to this point from the fact that there was consensus to research failures, cost to complete a research study, the cost of expansion devices, the cost of failure and replacement, and the lack of warranty on construction performance all of which is avoided by or not required from a contractor when install is badly performed and the cost in time and dollars to is borne by the public. Some examples are provided in Sec 4 of the guidance and from KDOT, see **Appendices B and C**.
29. Guidance on Construction Installation Sequencing with Thoughts on Practice:
30. Require on the plans (or BSPs) uniform hardware placement with uniform gaps parallel and transverse to fingers as part of the installation hold points across full length of the expansion device. Alignment is critical for a device that is vertically, horizontally, rotationally and laterally adjustable (from edge of slab on one side to edge of slab on the other side).
    1. Address construction practice on the plans with hold points before closure pours. Ensure construction/contractor meets installation instructions. This comes directly from the research which supports that poor construction can contribute to premature deterioration of both finger and flat plate expansion devices. With both types of devices, global rotation of spans or abutments, and uneven settlement can also contribute.
    2. Further, it may be a good idea to state on plans (or BSP) that engineer approval is required after final setting of device before final pour to ensure alignment. This is another “hold point” and is appropriate since the report heavily discusses poor construction installation practice as main leverage in requiring better inspection practice to ensure good and enduring service results.
31. Require that installation be as close to the average ambient temperature to allow for adequate expansion and contraction limits. AASHTO LRFD Bridge Design Specifications (AASHTO LRFD) suggests defining the average ambient temperature as that temperature measured over a 24 hour period which should be given as criterion on the plans for measurement for both contractors and construction inspectors.
32. Ensure properly consolidated and cured concrete. Hand packing concrete is recommended in AASHTO LRFD.
33. Fiber reinforced concrete would provide strong concrete encapsulation of finger plate hardware and is being considered for a research bridge letting. Self-consolidating concrete may even be a preferred option.
34. Install expansion device before deck slab is poured. This means placing device in the blockout. Final positioning would not be performed until blockout pour. Alternatively, device could be placed after deck pours. KDOT requires a ‘test run’ over a 24 hour period before final pour.
35. See ***Appendices B and C*** for KDOT installation sequencing for finger and flat plate expansion devices for review.
36. As provided by the research on the working (research) drawings:



*The exact language may change.*

1. Any improvement in the positioning ability over the current finger plate design is an improvement. However, more effort in setting may be required since there is more variability in all directions where none may have existed before.
2. Limits on optimum and maximum finger plate lengths will need to be developed for initial placement (constructing), and for considering future plate removal (maintaining), for example cleaning troughs, replacing troughs, overlays, plate replacement. Splice locations will need to be detailed.
3. Expected Revisions and Posts:

*Standard Drawing Revisions and EPG*

New Type A finger plate device standard drawings will be posted, while current finger plate device standard drawings will still be shown for jobs moving through the queue and for repair jobs over the next few years. EPG write-ups will follow after release/posting of the new standard drawings.

751.50 Notes review.

Type A finger plate device design information will be added to the EPG at this time.

Table of Type A Standard Drawings links will be added; current drawings will be retained for now.

A link to the research report will be added to the EPG section on expansion devices.

Type B finger plate expansion device will not be added to the EPG at this time.

Modify slab pouring sequence drawings for closure pour (make sure that closure pours are understood as ‘required’ and not ‘optional’)

Search, review and revise any affected articles; 751.50 Notes review.

*SharePoint Posts*

The example design calculations provided by HDR Engineering will be uploaded to SharePoint.

The design assumptions will be uploaded to SharePoint.

Type B details will be uploaded to SharePoint for approved use only at this time.

Design examples will be reproduced and made available to internal designers for review and future design revisions and augmentations or new designs.

Design assumptions for each finger plate type will be reproduced and made available to internal designers.

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APPENDIX A: On Notable Findings from the Research

*On Deterioration and Failure of Current MoDOT Finger Plate Device Designs*

1. “Quickest failure rate” may be on expansion devices that are poorly constructed or exposed to high traffic volumes.
2. “Highest failure rate” for finger plate devices seems to be on steel girders bridges.
3. “Most damage” for finger plate devices seem to be in cold weather when contraction is greatest and live load is maximized on expansion device and surrounding concrete.
4. “Damage” has been seen for high truck traffic counts and in the right driving lane of multi-lane roads.
5. Damage tends to occur on the more flexible side of two adjoining spans; and when the web stiffener spacing is greater.
6. 12 states use finger plates of the 22 that responded.
7. 12 of 12 states use LRFD for their designs. MoDOT will officially make it 13 since our design did not change from LFD and it is assumed it was not checked using LRFD.
8. Most states that use troughs of which there are 13, rarely if ever clean them. It is also important to note that the No.1 cause of failure of expansion devices that was reported from the survey was troughs. No. 2 was deteriorated concrete and No. 3 was snowplow damage. Therefore, if implemented, troughs should be routinely inspected with the expansion device, condition noted, flushed, repaired or replaced but in any event not ignored. On the design side, a trough slope will be used to promote effective flushing and mitigate buildup of debris. To give an idea of the cost difference, IDOT report $3000 to clean a trough and $400/ft to replace. Keep them clean and design the slope right so it is likely that they will last longer without a cleaning is ensured. KDOT reports that trough replacement is common.
9. Most states install devices completely before the deck is poured. Only one state install anchoring hardware before deck is poured and the remaining device after the deck is poured.

*On 22 State Transportation Departments-Survey*

FINGER PLATE DEVICES

1. 5 states use closure pours. Most states use regular concrete for closure pours. High strength concrete is used by two of them.
2. One state hand packs concrete AR. KS pours from low side to high side on both sides in all lanes.
3. 8 of 12 states use bolted, 4 uses welded and one state uses both in combination.
4. 8 of 14 states design for a service life more than 40 years.
5. 12 percent on average of all finger plates for all states reporting fail prematurely, i.e. replacement before a desired design life keeping in mind that each state has a different design life.
6. Deterioration of concrete adjacent to device is reported as No. 2 reason for failure for finger plates from survey; damage from snow plows next highest reported. No. 1 reason for damage is from drainage troughs with debris.

FLAT PLATE DEVICES

1. Only 5 states use them.
2. 22 percent on average of all flat plates for all states reporting fail prematurely, i.e. replacement before a desired design life keeping in mind that each state has a different design life for their designs.
3. 1 of 5 states design for more than 40 years (KS). 2 0f 5 are design that are 10-20 years
4. Deterioration of concrete reported as number one failure mechanism followed by snowplow damage and then fracture in welds in joint.
5. Deterioration of concrete adjacent to device No 1 for flat plates; damage from snow plows next highest

*On Problems with Current MoDOT Finger Plate Device Design*

Lack of redundancy for load path since its strength relies primarily on concrete remaining intact

Deficient overturning resistance

Undersized elements

Dependent on brittle welded connections especially at bottom of plate at interior of device which is most heavily stressed; use of welds in general

Stiffener plates spaced too far apart

Lack of adjustability of the device, longitudinally, transversely and rotationally (except vertical)

If poorly constructed, then outcome is poor performance

Vertical misalignment of finger from one span to adjacent span

Non-uniform placement of fingers from one side of roadway to transversely opposite side so that longitudinal joint opening varies

Non-uniform placement of fingers relative to their openings so that transverse joint opening is different on each side of a finger for all fingers (personal observation from field checks not in report)

Bridge movement can be source of misalignment if each side nonuniformly rotates or settles which cannot be corrected

*On Problems with Current MoDOT Flat Plate Device Design*

Welds

Lack of adjustability of the device

Continuity allows for bridge rotations to manifest as plate gaps

If poorly constructed, then outcome is poor performance

Requires good alignment during construction to get consistent support and contact between support angle and sliding plate

Misalignment of flat plate and landing vertically or rotationally

Bridge movement can affect plate stresses, for example if support beam deflects between girder lines or if an end bent settles or moves

Experimental dynamic testing showed that on average the dynamic strain along the device that are strain gaged about on avg 40% greater than the static strain , and at the fingers specifically were 70% greater strains. An impact factor of 100% was recommended by the research and also requested prior to the testing by MoDOT for an increased life of any new device. And on the support beam 38% increase was determined.

APPENDIX B: KDOT Finger Plate Device Construction Installation Sequence (Reprinted from KDOT)

1. Bring the anchor units to proper grade and alignment.
2. Position the support angles against the vertical support plates on the deck side anchor unit and clamp the support angles to the top flange of the supporting member.
3. Using the erection channels, spaced no greater than 4’-0”, bring the anchor units to the proper grade and into the same plane, centered over the gap between the girder ends and the front face of the abutment backwall. Set the top surface of the anchor unit parallel to the roadway slope. Check the scribe lines for proper alignment, then weld the support angles to the top flange of the supporting member.
4. Adjust the gap based on the average ambient air temperature during the previous 24 hours. See the table on the “Anchor Unit Details” sheet for the gap between anchor units. Tighten the top hex nuts in the erection channels and tighten the bolts connecting the support angles to the vertical support plates. Securely support the abutment side anchor unit.
5. Place the concrete for the abutment backwall. Thoroughly vibrate and compact the concrete around the anchor unit until concrete comes up through the vent holes and no voids exist under the anchor unit.
6. After the concrete has cured long enough to resist settlement or tilting of the anchor unit (2-3 hours), remove the erection channels.
7. Re-align the anchor unit on the deck side to proper alignment and grade with the finger plates in place. Tighten the bolts (using the torque values shown in the Specifications) connecting the support angles to the vertical support plates.
8. Remove the finger plates and place concrete around the deck side anchor unit. Again, thoroughly vibrate and compact the concrete around the anchor unit until concrete comes up through the vent holes and no voids exist under the anchor unit.
9. Three days after concrete placement the Engineer will check for voids and loose bolts by sounding the anchor plate. Fill any voids by drilling through the anchor plate and pumping in an approved epoxy mortar at a minimum of 75 psi. This work will be subsidiary to the bid item “Expansion Device (Finger Plate)”.
10. Install the fabric trough and the finger plates according to KDOT Specifications.
11. After installation of the finger plates, the Engineer shall inspect the plates for alignment. Any fingers that the Engineer determines are misaligned, so that they may be struck by a snow plow, shall be ground as directed by the Engineer.
12. Clean the trough of all foreign material after the completion of all superstructure work.

APPENDIX C: KDOT Standard Specification Sec 707 on Construction Installation (Abridged)

**b. Expansion Device (Finger Plate or Sliding Plate).** Place alignment marks on the anchor plates and finger plates or sliding plates on each side of the expansion gap to facilitate accurate installation.

Align the finger plate or sliding plate joint assemblies in position and check the expansion opening. The expansion opening must be adjusted for temperature prior to bolting, welding or placing concrete on each side of the joint. To adjust for the effects of sunlight on the girders, place reference marks on the bridge prior to sunrise. Use these reference marks to set the expansion opening using the table on the plans and the average ambient temperature over the previous 24 hours. Test fit the finger plates or sliding plates with all the armoring and anchorages in place. Install the finger joint centered over the expansion gap, for both finger plates and sliding plates. Verify that the joint is in plane and sloped per the roadway. For fingers plates, make sure the fingers do not rub during the full range of temperature movement.

The Engineer will confirm the procedure, opening and alignment prior to concrete placement. After confirmation, remove the finger plates or sliding plates before concreting. Place concrete around the joint and vibrate so the concrete paste comes up through the air vents and no voids exist under the anchor unit. Start concrete placement at the low end of the joint and work toward the high end. If the bridge has a normal crown, start at the edge and work toward the center from both sides. Three days after concrete placement, the Engineer will check for voids and loose bolts by sounding the anchor plate. Fill any voids by drilling through the anchor plate and pumping in an approved epoxy mortar at a minimum pressure of 75 psi. This work will be subsidiary to the bid item "Expansion Device (Finger Plate or Sliding Plate)".

Install the fabric trough and the finger or sliding plates according to the Contract Documents.

Thoroughly clean the top of the anchor plates to remove dried concrete paste before final assembly.

Lubricate anchor bolts with bee’s wax or equivalent and torque the nut according to

TABLE 707-1.

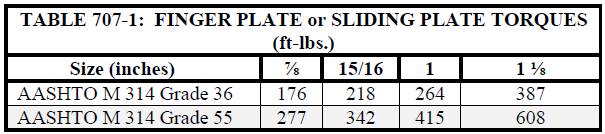
TABLE 707-1: FINGER PLATE or SLIDING PLATE TORQUES

(ft-lbs.)

Size (inches) ⅞ 15/16 1 1 ⅛

AASHTO M 314 Grade 36 176 218 264 387

AASHTO M 314 Grade 55 277 342 415 608



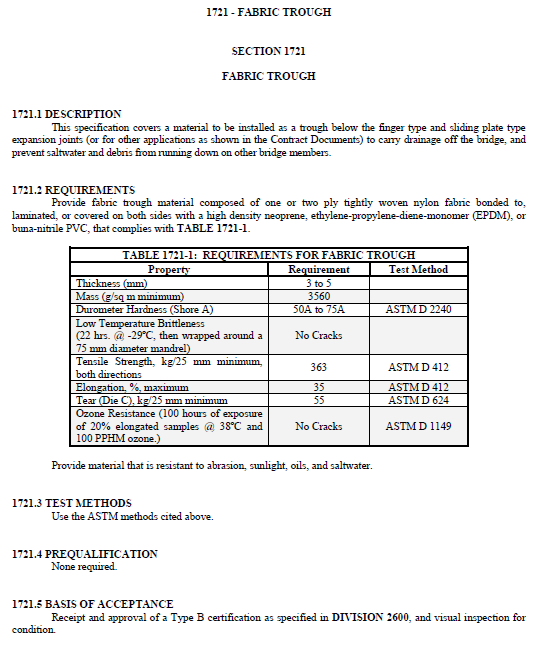
After installation of the finger plates or sliding plates, the Engineer will inspect the plates for alignment. Any plates that the Engineer determines are misaligned so that they may be struck by a snow plow, shall be ground as directed by the Engineer. This work will be subsidiary to the bid item "Expansion Device (Finger Plate or Sliding Plate)".

Install fabric troughs below the finger plate or sliding plate and clean the trough of all foreign material after

the completion of all superstructure work.

*(Note: MoDOT will use high strength A325 bolts for connecting finger plate to supporting plate and support beam flange.)*

APPENDIX D: KDOT Fabric Trough Specification



APPENDIX E: Essential Information from the Research on Proposed Type B Finger Plate Expansion

Device for Developing Standards

Proposed installation instructions from research report to be considered for implementing:

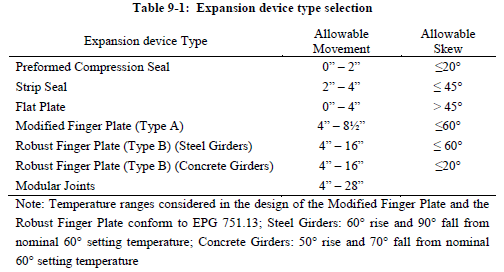
*(Reprinted from Research Report)*

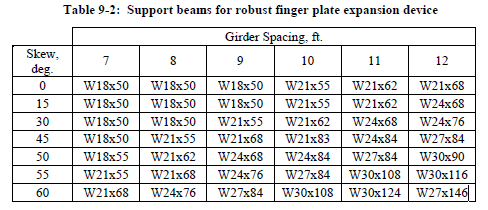
*(Installation criteria given below may either wholly or in part be used for* ***Type A*** *finger plate expansion device also. To be reviewed for applicability when developing standards.)*

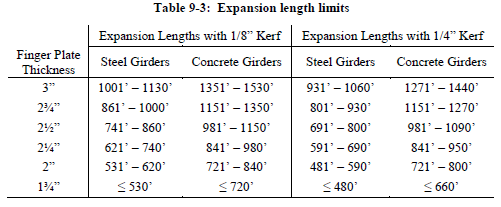
The majority of the deck concrete should be placed prior to setting the finger plate expansion device. A slab block out approximately five feet back from the expansion device should be placed after all deck pours are complete on both sides of the expansion device to avoid misalignment of the expansion device caused by girder rotations. Placement of the expansion device near the end of construction coupled with the adjustability of the expansion device will allow the device to be placed more accurately than the current design. The contractor should establish the roadway profile over the device after the adjacent concrete has been placed, including any adjustments necessary due to haunching corrections. The top surface of the device should be adjusted so that it is as close as possible to the adjusted profile but no more than 1/16” out of alignment. The opposite sides of the device should be aligned vertically so that they are also as close as possible to the same horizontal plane but no more than 1/16” different. The opposite sides of the device should be aligned transversely to maintain the expected kerf gap and should also be within 1/16” of the plan dimension. The device should be aligned along the bridge to sit on the dual support beams and the finger gap should be adjusted to the temperature at the time the device is set. After the device is set MoDOT construction personnel should check the alignment and placement of the device prior to field welding the bent plate supports to the top of the support beams. The 1/16” tolerances noted are tight and have been suggested to ensure close attention is paid to alignment and gap setting at time of construction due to the expensive nature of repairs. Final definition of construction tolerance should be investigated and adjusted upon implementation with MoDOT construction personnel for practicality.

The bolted design will allow the finger plate to be removed, shimmed and reattached during any overlay operation. The new finger plate expansion device designs can be seen in Figures 9-1 through 9-3. These details show the expansion device applied to an intermediate bent that is square to the alignment between two steel girder spans with a cast in place slab. Prestressed concrete deck panels can be used with these details but should not be placed in the area of the thickened slab. The expansion devices can also be skewed up to 60° by lengthening the support plates. The finger plate attachment bolts should be aligned to the direction of expansion. These details can also be modified to apply to prestressed concrete girder spans by elimination of the top flange of the girder within the thickened portion of the slab and by inclusion of formed holes in the web of the girder for the passage of the reinforcing cage. The need to pass the reinforcing cage through the web of the girder limits the skew angle that can be accommodated to 20°.

The use of recessed bolts in the finger plate increases the minimum plate thickness. This increased plate thickness will allow the use of straight finger geometry instead of tapered fingers used on the current standards. Straight fingers minimize the opening of the expansion device and provide increased safety for motorcycles during cold temperatures when the opening is greatest. Straight fingers also accommodate similar expansion lengths when the expansion device must be skewed. The finger plate thickness was designed for infinite life fatigue and the additional adjustment capacity of the expansion devices will prevent snags by snow plows reducing and/or eliminating the finger failure seen on older finger plate expansion devices with straight fingers. Table 9-3 shows the minimum finger thickness for a range of expansion lengths and two kerf widths between adjacent fingers. The concrete girder expansion lengths shown for the thickest plates are likely not practical but are included for comparison. The expansion device system is supported on a dual beam system for either steel or concrete girders which allows the formation of a support couple to resist the loads from the finger plate expansion device. This dual beam system should also be used to support the device under the overhang of the external girder by placement of support brackets. The optimal support beam size for a range of girder spacing and skews is shown in Table 9-2. Since the expansion device design is based on a tributary area loading, the placement of the devices can be phased if required. Similar to other expansion device types, the designer should avoid placing the phasing details in a permanent wheel path if possible. Since the expansion device support structure relies on the dual support beams, temporary support of the device may be needed if an adjacent girder is not going to be erected in the current phase and the deck and the device will overhang an interior girder. Phase lines at joint locations should be offset to align with edge of girder if possible to allow for installation of crossbeams in subsequent phases. An optional collection trough can be readily added to the expansion device if the expansion device is in an area where open drainage is not acceptable. Cover plates can be added if the expansion device is used in an area that needs protection for bicyclists, pedestrians and ADA guidelines.







Since expansion devices are often placed at the interface between bridge units it is likely for one side of the device to be anchored to a concrete girder or end bent while the other side is anchored to a steel girder. A minimum 1/16” gap between adjacent fingers should be maintained at all temperatures. Finger plates with a 1/8” kerf can accommodate a differential movement of 1/16” which equates to a bridge width of 63 feet. Finger plates with a ¼” kerf can accommodate a differential movement of 3/16” equating to a bridge width of 189 feet. Bridges wider than 189 feet should use an alternate expansion device such as a swivel version of a modular expansion device. Additionally, expansion devices in curved bridges with unguided bearings or bearings guided along the chord could experience differential movements which do not allow the designer to align the fingers to be coincident with movement from all directions. These movements should be limited to the tolerances of the selected kerf and the teeth should be oriented to bisect the chords or directions of movement from both sides of the joint. If the movements exceed the tolerances the bearings should be guided tangentially and guide systems sufficient to resist thermal forces to restrain movement provided by the designer. At end bents or intermediate bents with one side fixed the fingers should be skewed to the direction of movement.

The proposed Type B finger plate expansion devices were designed with the following criteria:

*(Reprinted from Research Report)*

• Straight fingers with a 1” radius throat and a 1/8” kerf during manufacture

resulting in a 1¾” wide finger or a ¼” kerf resulting in a 1½” wide finger.

• 1½” minimum gap at minimum expansion device opening and 1½” minimum

finger overlap during maximum expansion device opening.

• The finger thickness was designed based on Strength loading using the AASHTO

LRFD load factors and multi-presence factors and the following information:

o Increase impact to 100%.

o Design load is the design tandem with 25 kips / axle (12.5 kips / wheel).

o Each wheel is applied to a 10” x 20” area placed at the tip of the fingers on one

side of the expansion device so that the centroid of the load is 5” from the tip of

the fingers.

o Assume the entire wheel load is taken by one side of the expansion device.

o Design moment is taken at the beginning of the finger throat (1” away from the

extreme throat).

o Disregard plastic capacity of the finger and limit the moment capacity to first

yield.

o A practical maximum finger thickness of 3” works for a total factored movement

of 16” which equates to a bridge expansion length of 1130 feet if steel girders

and a 1/8” kerf are used.

• The selected finger thickness was checked for infinite life Fatigue loading using

the AASHTO LRFD load factors and the following information:

o Increase impact to 100%.

o Fatigue load is the HL-93 truck with the heavy axle assumed to be a tandem with

16 kips / axle (8 kips / wheel) in accordance with the fatigue design of

orthotropic decks as shown in AASHTO Fig. 3.6.1.4.1-1 and also in accordance

with the fatigue design for Modular Bridge Joints as shown in AASHTO

14.5.6.9.4.

o Each wheel is applied to a 10” x 20” area center placed at the tip of the fingers

on one side of the expansion device so that the centroid of the load is 5” from

the tip of the fingers.

o Assume the load is shared between both sides of the finger plate expansion

device proportional to the overlap at 30°F, a conservative assumption for the

normal use of the expansion device.

o Consider the throat of the finger to be a Class B material with ΔTH = 16 ksi.

• The finger plate attachment bolts were designed as a couple with the near bolt in

compression and the far bolt in tension; designed for both Strength and Fatigue.

• The anchor plate and support plate system was designed for both Strength and

Fatigue using conservative assumptions. This design was verified by FEM

modeling.

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