Minnesota Department of Transportation

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TRANSMITTAL NOTICE (2016-03)		**ISSUED BY**	Bridge Office
MANUAL	LRFD Bridge Design Manual	**DEVELOPED BY**	Bridge Office
SUBJECT	Title Page Table of Contents Section 1: Introduction Section 3: Loads and Load Factors Section 4: Structural Analysis and Evaluation Section 5: Concrete Structures Section 8: Wood Structures Section 11: Abutments, Piers, and Walls Memos		

The MnDOT Bridge Office *LRFD Bridge Design Manual* is available for download in *Adobe* PDF (Portable Document Format) at http://www.dot.state.mn.us/bridge/. This Web site should be checked regularly for updates.

INSTRUCTIONS:
(for two-sided printing)

1. Remove from the manual:
   - Title Page
   - Table of Contents pages iii through xii
   - Pages 1-9 and 1-10
   - Entire Section 3
   - Pages 4-5 and 4-6
   - Pages 5-1, 5-2, and 5-9 through 5-14
   - Pages 8-117 and 8-118
   - Pages 11-7, 11-8, 11-13, and 11-14
   - Remove Memo to Designers (2005-02), (2005-03), and (2006-01)

2. Print and insert in the manual:
   - Title Page
   - Table of Contents pages iii through xii
   - Pages 1-9 and 1-10
   - Entire Section 3
   - Pages 4-5 and 4-6
   - Pages 5-1, 5-2, 5-9 through 5-14, and 5-137 through 5-146
   - Pages 8-117 and 8-118
   - Pages 11-7, 11-8, 11-13, and 11-14

Note: In the "AUGUST 2016" update, some minor errors are being corrected, some clarifications are being added, and some guidance is being revised. Changes include:

- Section 1: Correction regarding when a structure is assigned a bridge number.
- Section 3: Updates regarding wind loads, correction to Table 3.3.1 regarding unit weight of compacted fill on box culverts, clarification on double truck modification, and renumbering of some articles.
- Section 4: Correction of a table reference.
- Section 5: Correction to Table 5.1.1.1 regarding concrete mix designation, update to reinforcing bar development lengths and splices, hooked bar development lengths, and minimum bar spacing. Also added appendix containing rebar lap splice guide.
- Section 8: Correction of 2 subheadings.
- Section 11: Correction of Figure 11.1.1.1a to show keyways and correction of error regarding integral abutment stem dowel embedment.
- Removal of obsolete Designer Memos.

Any ***technical questions*** regarding this transmittal should be directed to Dave Dahlberg, Bridge Design Manual and Policy Engineer, at dave.dahlberg@state.mn.us or 651/366-4491.

Kevin Western
State Bridge Engineer

MANUAL

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MINNESOTA DEPARTMENT OF TRANSPORTATION

Bridge Office

LRFD Bridge Design Manual

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APPENDIX A. MEMOS

1.2.2 Highway Systems

Highways throughout the nation are divided into systems. These system designations are important to know because design standards can vary between the systems. The various highway systems are classified according to the Agency that has responsibility for their improvement, maintenance and traffic regulation enforcement. Listed below are the jurisdictional divisions in Minnesota:

1) Trunk Highway System
   The Trunk Highway System consists of all highways, including the Interstate routes, under the jurisdiction of the State of Minnesota. These routes generally are the most important in the state, carry the greatest traffic volumes, and operate at the highest speeds.
2) County Highway System
   The County Highway System is made up of those roads established and designated under the authority of the county board. They generally are the more important routes within a county that are not on the Trunk Highway System.
3) Township Road System
   The Township Road System is made up of the roads established under the authority of the town board. They generally are of local importance.
4) Municipal Street System
   The Municipal Street System is all roads within a municipality not designated as a trunk highway or county road. They are generally of local importance.

1.2.3 Bridge Numbers

All publicly owned bridges, either on or over a trunk highway, that are 10 feet or more in length measured along the centerline of the highway, are assigned a number for identification and cost accounting purposes.

The numbering scheme followed in assigning bridge numbers depends on the time of construction. With few exceptions, the numbering procedure is as follows:

1) Prior to about 1950, all bridges were numbered consecutively from 1 to 9999 as they were constructed. The 8000 series was used for culverts over 10 feet in length (measured along the centerline of the highway). The 7000 series was reserved for county bridges at trunk highway intersections. Five-digit bridge numbers beginning with L or R designate bridges in local bridge systems.

2) Since about 1950, a five-digit number has been assigned to each bridge as it was constructed. The first two digits coincide with the county number (01-87) in which the bridge is located (99 refers to temporary bridges). The last three digits are assigned consecutively using the following guidelines:

a. 001-499 are used for regular trunk highway bridges.
b. 500-699 are used for county bridges.
c. 700-999 are used for interstate bridges (any bridge on or over the interstate system).

3) In 1991, additional numbers were required for bridges on the state aid system in Hennepin County and for interstate bridges in Hennepin County. To allocate more numbers for bridges on the local system an alpha character is used as the third character of the bridge number. For example, the next bridge number after Bridge No. 27699 will be Bridge No. 27A00. Note that this happens only after 500 and 600 series have been exhausted.

To allocate more numbers on the Interstate road system, the 400 series of numbers will be used along with the 700, 800, 900's presently used. For a bridge number XXYZZ, the following now applies:

XX = County identification number (99 = Temporary Bridge)
Y = 0, 1, 2, 3, or R, T, U (for Trunk Highway Bridges)
Y = 4, 7, 8, 9, or V, or W (for Interstate Bridges)
Y = X and Y (Trunk Highway or Interstate Culverts)
Y = 5 or 6 or A through H (for non-trunk highway Bridges)
Y = J through N, and P, Q (for non-trunk highway Culverts)
ZZ = Sequence number (00 through 99)

As of September, 2006, the following numbering scheme was added for:
- Bridges or culverts without a highway over **or** under (e.g. pedestrian trail over stream)
- Existing bridges that have not been assigned a bridge number
- Skyways and other miscellaneous structures such as conveyors, pipelines, or buildings

Use the format R***ZZZZ*** where:
R = A literal character
ZZZZ = Sequence number (0000 thru 9999)

4) In cases of twin bridges, a westbound or southbound lane bridge is generally assigned a lower number than an eastbound or northbound lane bridge.

All bridge numbers are assigned by the Bridge Office. A complete listing of all numbered bridges is available in computer printout form entitled "Minnesota Trunk Highway Bridge Log- Statewide Listing". See Table 1.2.3.1 for a listing of the county identification numbers.

3. LOADS AND LOAD FACTORS

The loads section of the AASHTO LRFD Specifications is greatly expanded over that found in the Standard Specifications. This section will present applicable loads and provide guidance to MnDOT's practice for the application of these loads.

3.1 Load Factors and Combinations [3.4.1]

The standard load combinations for LRFD design are presented in LRFD Table 3.4.1-1.

Several of the loads have variable load factors (e.g., γ_P, γ_{TG}, γ_{SE}). The load factors for permanent loads (γ_P) typically have two values, a maximum value and a minimum value. When analyzing a structure it will often be necessary to use both values. The objective is to envelope the maximum load effects on various elements for design. A box culvert structure illustrates the use of both values. When determining the moment in the top slab of a culvert, the maximum load factor is used on the vertical earth loads, while the minimum load factor is used on the lateral or horizontal earth loads. The situation reverses when determining the moments in the wall of a culvert. A minimum load factor is used on the vertical earth loads and a maximum value is used on the horizontal earth loads.

When assembling load combinations, do not use more than one load factor for any load component. For example, when checking uplift, a load factor of 0.90 or 1.25 should be used for the dead load on all spans. Designers should not try to use 0.9 on the span adjacent to the uplift point and 1.25 on the next span.

Designers must ensure that structures have been checked for adequacy in carrying all appropriate load combinations at all construction stages. For example, check a high parapet abutment for any permissible construction case in addition to the final condition. The abutment may be completely constructed prior to placement of the beams (a case which maximizes the horizontal earth pressure load with a minimum of vertical load) or the abutment could be constructed such that the superstructure is completed prior to backfilling (a case which maximizes vertical load without horizontal earth pressure load). Designers are to investigate both cases. For complex structures, designers are responsible for providing one workable construction sequence in the bridge plan and checking for adequacy at all the construction stages. If the contractor proposes a different construction sequence, the contractor is responsible for confirming structure adequacy at all the construction stages.

Load Combinations

The load factors and the combination of different load components presented in LRFD Table 3.4.1-1 have been calibrated to produce structures with more uniform reliability than that offered with Standard Specification designs. The Extreme Event I load combinations will rarely control in Minnesota. Note that designs must also consider the load combinations for construction loading.

Strength I: Basic load combination used to determine the flexural and shear demands without wind.

Strength II: Basic load combination used to determine the flexural and shear demands of a structure subject to a permit vehicle or a special design vehicle specified by the owner. MnDOT does not typically use special vehicles for design. See Article 3.4 for more information.

Strength III: Load combination used to determine flexural and shear demands that include a design wind based on a 3-second gust wind speed of 115 mph.

Strength IV: Load combination relating to very high dead load to live load force effect ratios. Use the following modified Strength IV load combination, given in AASHTO LRFD Article C3.4.1:

[C3.4.1] 1.4DC + 1.5DW + 1.45LL

Note that Strength IV only applies to superstructures. It does not apply to investigation of construction stages, substructures, retaining walls, or bearings.

Strength V: Load combination corresponding to normal vehicular use of the bridge concurrent with a design wind based on a 3-second gust wind speed of 80 mph.

Extreme Event I: Load combination including earthquake effects. Earthquake analysis is typically not performed.

Extreme Event II: Load combination corresponding to ice loads, collision loads, and certain hydraulic events with a reduced vehicular live load. This combination is used for barrier design, deck overhang design, and pier design per the pier protection policy found elsewhere in this manual.

Service I: Load combination used for the design of many elements. It is used for service load stress checks (prestressed concrete), deflection checks, crack control checks in reinforced concrete, etc.

Service II: Load combination used to check yielding and connections in steel structures.

Service III: Load combination used to check outer fiber tension stresses and web principal stresses in prestressed concrete structures.

Fatigue I: Load combination used for the design of structures subject to repetitive live load. It is used for checking infinite load-induced fatigue life.

Fatigue II: Load combination used for the design of structures subject to repetitive live load. It is used for checking finite load-induced fatigue life.

[3.4.2] **Construction:** All appropriate load combinations must be considered by designers for construction loads. Use the load factors given in AASHTO LRFD Article 3.4.2 for construction loads.

3.2 Load Modifiers [1.3.3, 1.3.4, 1.3.5]

For most structures, each of the load modifiers will be 1.00. For a limited number of bridges, load modifiers with values different from 1.00 need to be used. Table 3.2.1 summarizes MnDOT's policy for load modifiers.

Note that load modifiers apply only to the strength limit state. For all other limit states, use a value of 1.00 for all load modifiers. Load modifiers need not be applied to construction load cases.

Table 3.2.1
Standard MnDOT Load Modifiers

Modifier	Value	Condition
Ductility (η_D)	1.00	Steel structures, timber bridges, ductile concrete structures
	1.05	Non-ductile concrete structures
Redundancy (η_R) *	1.00	Redundant
	1.05	Non-redundant
Importance (η_I) **	0.90	Temporary Bridges
	0.95	ADT < 500
	1.00	500 ≤ ADT ≤ 40,000
	1.05	Major river crossing or ADT > 40,000 on bridge or Mainline interstate on bridge

* Beam type superstructures with 4 or more beams per span are considered redundant

** Use Importance load modifier for design of the superstructure only, except do not apply to deck designs for deck-on-girder type bridges. Use only on new bridges.

3.3 Permanent Loads (Dead and Earth) [3.5]

To reduce the number of load factors considered through the design process, use a value of 0.020 ksf for the future wearing surface load and combine with the other component dead loads (DC loads). Also, combine the load due to a concrete wearing course with other DC loads. Apply utility loads as DW loads with the appropriate AASHTO load factor.

Table 3.3.1 lists unit weights for a number of materials. Designers should note that several of these items differ slightly from the values contained in Section 3 of the LRFD Specifications.

Table 3.3.1
MnDOT Standard Unit Weights

Material	Unit Weight (kcf)
Bituminous Wearing Course	0.150
Cast-In-Place Concrete	0.150
Precast Concrete	0.155
Precast Box Culvert	0.150
Compacted Fill on Box Culverts	0.120
Standard Fill	0.120
Steel	0.490
Timber	0.050
Water	0.0624

3.4 Live Loads [3.6]

HL-93 is the designation for the calibrated design live load provided in the LRFD Specifications. It should be considered the normal design load for MnDOT highway structures.

For pedestrian bridges, in addition to the pedestrian live load, design for a maintenance vehicle live load equivalent to an H-5 truck for deck widths from 6 to 10 feet, and an H-10 truck for wider decks. Use of the dynamic load allowance is not required with the maintenance vehicle.

Where appropriate, additional live loads should be considered. Additional live loads might include:

- MnDOT bridge inspection vehicle loads on bridges with large overhangs.
- MnDOT standard permit trucks on complex bridge types such as curved steel or post-tensioned concrete boxes. Discuss with the Bridge Ratings Engineer.
- Incorporate a live load surcharge into the design when construction or maintenance equipment will operate adjacent to retaining walls and abutments.

3.4.1 HL-93 Live Load, LL [3.6.1.2]

Use the design truck, fatigue truck, design tandem, truck train and lane loads described in the LRFD Specifications.

For simple spans, Tables 3.4.1.1 and 3.4.1.2 at the end of this section list the unfactored moments and shears for HL-93 loading on span lengths between 1 and 200 feet.

For continuous beam spans, internal studies have led to MnDOT modifications to the double truck live load given in LRFD Article 3.6.1.3.1. The modifications ensure adequate load ratings for the MnDOT standard permit trucks. In lieu of 90% of the HL-93 double truck stated in the LRFD Specifications, use the following live load for determining negative moments and interior pier reactions:

- For bridges with longest span ≤ 60 feet, apply 125% of the HL-93 double truck with dynamic load allowance plus lane load.
- For bridges with longest span > 60 feet, apply 110% of the HL-93 double truck with dynamic load allowance plus lane load.
- Do not use the double tandem loading described in LRFD Article C3.6.1.3.1.

Note that these modifications apply to continuous beam spans only. For simple spans, follow LRFD Article 3.6.1.3.1 as written for determination of interior pier reactions.

3.4.2 Multiple Presence Factor, MPF [3.6.1.1.2]

When a structure is being evaluated for load cases involving more than two lanes of traffic a reduction factor or multiplier can be used. This factor recognizes the reduced probability that all lanes will be fully loaded at the same time. Note that the LRFD Specifications require a 1.2 factor to be used for the design of structures carrying a single lane of traffic.

3.4.3 Dynamic Load Allowance, IM [3.6.2]

What was known as impact in the Standard Specifications is called dynamic load allowance in the LRFD Specifications. The base dynamic load allowance factors are presented in LRFD Table 3.6.2.1-1. Designers should note that the base values are reduced for buried components and for wood structures.

3.4.4 Pedestrian Live Load, PL [3.6.1.6]

Pedestrian live loads vary with the function of the bridge. For conventional highway bridges with sidewalks wider than two feet, use an intensity of 0.075 ksf.

For pedestrian bridges, refer to the *Guide Specifications for Design of Pedestrian Bridges* for the pedestrian live load to be used.

3.4.5 Braking Force, BR [3.6.4] [3.6.1.1.1]

Use judgment when applying braking forces to a structure. For one-way bridges, apply the braking force in all AASHTO defined design lanes. For bridges striped as two-lane, two-way bridges, apply the braking force in one direction in both traffic lanes. For two-way bridges with more than two striped traffic lanes, determine the traffic direction with the greatest width (including width of any sidewalks and pedestrian trails adjacent to traffic) and apply the braking force to the number of AASHTO defined design lanes that fit within that width.

The dynamic load allowance factor is not applied to braking forces. However, multiple presence factors are to be used.

For pier design, braking forces are to be applied at a height 6 feet above the roadway surface and in a longitudinal direction. In bridges where there is not a moment connection between the superstructure and substructure (i.e., beam bridges on bearings), the braking force can be assumed to be applied to the pier at the bearings.

3.4.6 Centrifugal Force, CE [3.6.3]

Similar to braking forces, multiple presence factors are to be applied to the centrifugal force, while the dynamic load allowance is not applied.

Apply the centrifugal force at a height of 6 feet above the top of the deck.

3.4.7 Live Load Application to Buried Structures

For buried structures, a lane plus a design truck or tandem is applied to the roadway and distributed through the fill. If the fill is 2 feet or less, the live load is applied as a footprint to the top of the structure. For fills over 2 feet, the footprint load spreads out through the soil fill. Refer to Article 12.2.3 of this manual for more information on application of live load to box culverts.

3.4.8 Live Load Surcharge, LS [3.11.6]

Retaining walls and abutments typically need to be designed for load combinations with live load surcharge. The equivalent soil heights to be used for different heights of abutments and retaining walls are provided in LRFD Tables 3.11.6.4-1 and 3.11.6.4-2.

3.5 Water Loads, WA [3.7]

Some of the hydraulic event terminology used in the MnDOT hydraulic report differs from that used in the AASHTO LRFD Specifications (LRFD):

- The MnDOT "design flood" for a structure is based on the average daily traffic that passes over the structure with the maximum design flood being a 50-year flood. (Refer to Section 3.2 of the MnDOT Drainage Manual for more information.) This is used as part of a roadway and surrounding property risk assessment done by the Hydraulics Section.

[2.6.4.4.2 and 3.7.5]

- The LRFD "design flood" for a structure is the lesser of the overtopping or 100-year flood. Use the LRFD "design flood" water and scour elevations (the 100-year flood is called out as the "basic flood" in the MnDOT hydraulic report) when analyzing piers for stream pressure loads under the strength and service limit states.

- The "check flood for scour", as defined by LRFD, is the lesser of the overtopping or 500-year flood. Use the LRFD "check flood for scour" water and scour elevations when analyzing piers for stream pressure loads under the extreme event limit state as follows:

    - Check piers using Extreme Event II for the full "check flood for scour" water and scour elevations. Do not include any BL, IC, CT, or CV loads for this check.
    - Check piers using Extreme Event II for applicable BL, IC, CT, or CV loads. For this case, use 50% of the water and scour from the "check flood for scour".

Design structural elements for both the no scour condition and the anticipated scour condition.

3.6 Wind Loads [3.8]

Wind loads are based on the design 3-second gust wind speeds given in LRFD Table 3.8.1.1.2-1. Use a design 3-second gust wind speed of 115 mph for the Strength III limit state.

3.6.1 Wind Load on Structure, WS [3.8.1.2 & 3.8.2]

For design of substructures, use the following guidance regarding wind loads applied to ornamental metal railing or chain link fence:

- For Standard Figures 5-397.160 and .161, Ornamental Metal Railing with Fence (Design T-3), assume 50% of the combined rail/fence surface area is solid.
- For Standard Figures 5-397.162 and .163, Ornamental Metal Railing (Design T-4), assume 30% of the rail area is solid.
- Calculate the rail surface area for other standard and non-standard ornamental metal rails.
- For chain link fence, assume 30% of the fence area is solid.
- When determining the moment arm for pier design due to wind acting on the superstructure, assume the wind pressure acts on the full height of the ornamental metal rail or chain link fence.

Do not use these loads for ornamental metal railing or chain link fence design. Refer to LRFD Section 13 for railing design.

The vertical overturning wind load described in LRFD Article 3.8.2 must also be considered in design.

3.6.2 Wind on Live Load, WL
[3.8.1.3]

Consider the force effects of wind on live load for the Strength V and the Service I load combinations.

Apply the wind on live load forces at a height 6 feet above the top of the deck. In bridges where there is not a moment connection between the superstructure and substructure (i.e., beam bridges on bearings), the longitudinal component of the wind on live load force can be assumed to be applied to the pier at the bearings.

3.7 Earthquake Effects, EQ
[3.10]

All of Minnesota is in Seismic Zone 1 with acceleration coefficients varying between 2 and 3 percent. With very small acceleration coefficients, earthquake forces will rarely govern the design of MnDOT structures. However, Seismic Zone 1 structures must satisfy AASHTO requirements pertaining to the length of superstructure bearing seats and the horizontal design connection force between the superstructure and substructure.

[4.7.4.4]

For expansion bearings, check that the actual length of bearing seat, N_{act}, satisfies LRFD Article 4.7.4.4 using a Percentage N equal to 75.

[3.10.9.2]

For fixed bearings and anchors, MnDOT has modified the required horizontal connection force given in AASHTO. Design for a minimum horizontal connection force equal to 15% of the Strength I limit state vertical reaction.

3.8 Ice Loads, IC
[3.9]

The design ice load is 1.5 feet of ice with a crushing strength of 32.0 ksf. Assume the ice load is applied at a height two-thirds of the distance from the flowline elevation to the lesser of the 100-year flood or overtopping flood high water elevation. Use a friction angle θ_f equal to 0 degrees between the ice and pier nose.

3.9 Earth Pressure, EV, EH or ES
[3.5.1, 3.5.2]
[3.11.5, 3.11.6]

For cast-in-place cantilever concrete retaining walls, refer to the "Basis of Design" found on standard plan sheet 5-297.639 for determination of earth pressure loads. For other types of retaining walls, follow the current *AASHTO LRFD Bridge Design Specifications*.

For applications with level backfill other than retaining walls, simplified equivalent fluid methods can be used for determination of lateral earth pressure loads (EH). For parapet and semi-integral abutment stems, design for an active earth pressure of 0.033 kcf equivalent fluid weight. For level backfill applications where at-rest earth pressures cannot be relieved, design for an equivalent fluid weight of 0.060 kcf. Assume that the horizontal resultant for lateral earth pressures acts at a height of H/3.

For integral abutments and semi-integral abutment diaphragms, design for passive earth pressure loads. See Article 11.1.1 of this manual for load application.

For the vertical earth loads (EV) applied to pier footings, use a maximum load factor of 1.35 and a minimum load factor of 0.90.

3.10 Temperature, Shrinkage, Creep, Settlement, TU, SH, CR, SE [3.12]

Temperature, shrinkage, creep, and settlement produce several structural effects. They generate internal forces, redistribute internal forces, and produce movements.

As an alternative to AASHTO, the *CEB-FIP Model Code for Concrete Structures, 1990*, may be used to determine time dependent effects of concrete in post-tensioned structures.

3.10.1 Temperature Effects

One of the most ambiguous tasks for bridge designers is the determination of the appropriate temperature range and corresponding deformations for use in calculating force effects on a structure. Past MnDOT practice has been to design concrete frames for a 45°F temperature fall and a 35°F temperature rise, a temperature range smaller than what the bridge will actually experience during its service life. This method dates back to the 1920s, and the reduced temperature range should be considered a “rule of thumb” that was applied to typical bridges using simplified analysis methods of the time. No notable performance issues have been attributed to application of a lower thermal temperature range when applied to pier frames or relatively short span bridges. On complicated, longer span bridge frames, longitudinal thermal effects become a larger issue that designers should not ignore. Therefore, the following policy is to be used for application of thermal loads on typical and non-typical bridges.

Typical Bridges

Typical bridges include:

- routine multiple span prestressed beam, steel beam, and slab bridges

- bridges with two or fewer fixed piers
- bridges with piers less than 30 feet tall

[3.12.2.1] For typical bridges, use LRFD Procedure A for internal pier frame forces due to thermal expansion. For concrete frames, Procedure A allows for a temperature range of 80°F. Use a base construction temperature of 45°F, which corresponds to designing for thermal force effects due to a 45°F temperature fall and a 35°F temperature rise. In addition, apply the strength limit state load factor of 0.5 for calculation of thermal force effects and use gross section properties in the analysis. The 0.5 load factor accounts for the reduction in thermal forces due to cracking of the concrete.

[3.12.2.2] For longitudinal effects, use a temperature range of 150°F (-30°F to 120°F), which is the approximate range given by LRFD Procedure B for Minnesota's climate. Use a base construction temperature of 45°F and apply the strength limit state load factor of 0.5 for calculation of thermal force effects while using gross section properties in the analysis. Also, see Article 14.1 of this manual for guidance on fixity and thermal movements.

Design expansion joint openings for movements associated with a temperature range of 150°F (-30°F to 120°F). For strip seal expansion joints, use a load factor for movement of 1.0. (Note that this value differs from the LRFD Specifications based on past performance of joints in Minnesota.) For modular expansion joints, use a load factor for movement of 1.2 per LRFD Article 3.4.1. See Article 14.2 of this manual for more guidance on expansion joints.

Design bearings for movements associated with a temperature range of 150°F (-30°F to 120°F) and a base construction temperature of 45°F. For computation of movement for the elastomeric pad minimum compressive stress check, use a load factor of 1.0. For computation of movement to determine minimum elastomer thickness, use a load factor of 1.3. (Note that these load factors differ from the LRFD Specifications and are based on past performance of elastomeric bearings in Minnesota.) For computation of movement for design of pot and disc bearings, use a load factor of 1.2.

Non-Typical Bridges

Non-typical bridges are those with tall or slender piers or those with long spans. For these bridges, the pier stiffness is critical in determining movements and forces, and a refined analysis must be used to reduce force effects due to thermal movements and other loads.

[3.12.2.2] For non-typical bridges, use a temperature range of 150°F (-30°F to 120°F) for longitudinal effects, which is the approximate range given by LRFD Procedure B for Minnesota's climate. When analyzing bridges with this larger thermal range, the designer must consider the following in the analysis:

- Pier stiffness – Use refined method to determine the appropriate percentage of gross stiffness along the height of the pier.
- Bearing fixity and flexibility – Account for the stiffness of expansion bearings in determination of the overall bridge movements.
- Construction method, staging, temperature range at erection, and its effect on the connectivity of the structural system.
- Foundation stiffness – Elastic shortening of the piles provides a significant relaxation to forces applied to the pier. Also, horizontal displacements of piling will provide moment reduction.
- For joint and bearing sizing, use a 150°F range at Service Limit State conditions. Use a thermal movement load factor of 1.2. Also use this movement to determine horizontal force requirements for guided bearings.
- For Strength Limit State, use a thermal load factor of 1.0 with the 150°F range for longitudinal force effects. For transverse effects within individual pier frames, an 80°F range with a 45°F base construction temperature may be used.

A 3-D model of the bridge with appropriate elastic restraints at supports may be required (especially for curved bridges) to determine the direction of movement, magnitude of thermal forces, and interaction between piers for determination of the appropriate cracked section reduction in stiffness. The final solution may require several iterations and may be bracketed using an upper-bound and lower-bound stiffness matrix (i.e., - gross sections, partially cracked sections, etc.) so that the final solution falls within an acceptable range for the particular structure.

In cases where several piers are fixed to the superstructure, consideration of ambient temperature at anticipated time of construction (including adjustments for closure pours as necessary) should be considered. Setting of bearings and joints within the structure may require special provisions that call for contractor submittals which state the intended method of bearing and joint installation to obtain a neutral position at the mean temperature.

Some non-typical bridges will consist of multiple units (where a unit is defined as the number of spans between expansion joints) with multiple bridge types, where not all units are non-typical. For example, a major river crossing may consist of 3 units: a multi-span slab type approach unit, a single main span tied arch unit, and a pretensioned concrete beam approach unit. If the approach units fit the typical bridge category, a refined analysis for pier stiffness determination is not required for the approach units. However, use of a thermal movement load factor of 1.2 is still required for joint and bearing sizing in the typical units.

3.10.2 Shrinkage Effects

Use a design relative humidity to 73% for concrete shrinkage computations.

3.11 Pile Downdrag, DD

For situations where long friction piles or end-bearing piles penetrate through a soft, compressible, top layer of material, long term settlement of the soft layer may introduce a downdrag load to the pile as it grips the pile through negative skin friction. An estimate of the downdrag load will be given in the Foundation Engineer's Memo and the amount of downdrag load to consider in design will be specified in the Foundation Recommendations. See Section 10.1.2 of this manual for more discussion on downdrag.

3.12 Friction Forces, FR [3.13]

Friction forces are used in the design of several structural components. For example, substructure units supporting bearings with sliding surfaces should be designed to resist the friction force required to mobilize the bearing.

3.12.1 Sliding Bearings

LRFD Table 14.7.2.5-1 provides design coefficients of friction for PTFE sliding surfaces.

3.12.2 Soil/Backwall Interface and Soil/Footing Interface

Use LRFD Table 3.11.5.3-1 to obtain the coefficients of friction between the backwall/footing and soil. When cohesionless backfill is used behind a vertical or near vertical wall, the friction between the backwall and the backfill can be ignored.

When evaluating the sliding resistance between a concrete and soil interface, a coefficient of 0.80 shall be used. For cases where a shear key is utilized, the portion of the failure plane with soil on both sides should be evaluated with a coefficient of friction of 1.00.

3.13 Extreme Event

The probability of extreme event loads occurring simultaneously is extremely small and therefore, is not to be applied concurrently. In some cases, extreme event loads are mutually exclusive. A vessel collision load can not occur when the waterway is iced over.

For the extreme event cases with ice (IC) or vessel collision (CV), evaluate bridges for 50% of the 500 year scour event depth.

3.13.1 Vehicle Collision, CT [3.6.5]

Designers need to be concerned with vehicle collision loads. Unprotected structural elements that may be struck bluntly by a vehicle or train shall be protected or be designed to resist the collision force Review the Preliminary Plans to determine what is required. Also, see Section 11.2.3 of this manual for complete pier protection policy and requirements.

There are two documents which contain crash test criteria for bridge railings and barriers. They are *NCHRP Report 350* and the more recent *Manual for Assessing Safety Hardware.* The performance of barriers is classified with different test levels ranging from TL-1 to TL-6.

Decks supporting safety barriers designed to contain errant vehicles on bridges shall be designed for collision forces consistent with roadway standards. In most cases, the minimum standard for safety barriers on bridges carrying high speed traffic in Minnesota is Test Level 4 (TL-4). Under certain circumstances, reduced test level requirements may be acceptable. For example, TL-3 may be adequate for buried structures. See Section 13 of this manual for additional guidance.

3.13.2 Vessel Collision, CV [3.14]

Structures within reaches of the Mississippi, Minnesota, and St. Croix rivers, and Lake Superior deemed navigable by the Corps of Engineers shall be designed to resist vessel collision loads.

3.14 Uplift

For curved bridges with skews or continuous bridges with spans that vary significantly, there is a possibility of uplift at the end supports. For situations where a sidespan is less than 70% of the adjacent continuous span, uplift should be considered. Uplift may occur during construction if deck placement is not sequenced properly or during service due to the application of live load if the spans are not balanced. If uplift occurs, the performance of the bearings and expansion joints may be compromised.

[Table 3.4.1-2]

When evaluating a structure for uplift the load factors for permanent load should be reviewed. Minimum and maximum factors shall be combined for different elements to generate the most conservative or largest uplift force effect.

3.15 Construction Loads

The designer must consider construction loads during design. The diaphragm spacing and top flange dimensions in the positive moment region of the steel beam superstructures are based on the construction load stage. Specialty structures such as segmental concrete bridges have unique construction loads to consider during design that are explicitly defined. Unless project specific information is available or necessary, use the following loads:

Formwork
For conventional formwork (plywood, etc.) assume a uniform dead load of 0.010 ksf. In addition to dead loads, design concrete formwork for a construction live load of 0.050 ksf.

Structural Elements
Structural elements that support formwork are assumed to have a larger tributary area and consequently are to be designed for a smaller construction live load of 0.020 ksf.

Consider reconstruction loads when designing end diaphragms. At abutments, design end diaphragms to carry vertical jacking forces during bearing replacement.

3.16 Deflections [2.5.2.6.2]

MnDOT's maximum permitted live load deflection for highway bridges without sidewalks is $L/800$. For highway bridges with sidewalks, the limit is reduced to $L/1000$.

For typical deck-on-beam bridges that meet the LRFD Table 4.6.2.2.2b-1 and 4.6.2.2.2d-1 "Range of Applicability", use the following load distribution when computing deflections:

Live Load:

$$\text{Live Load Distribution Factor} = \text{MPF} \cdot \left[\frac{\#\ \text{Lanes}}{\#\ \text{Beams}}\right]$$

Dead Load:

$$\text{Dead Load (per beam)} = \left[\frac{\text{Total DC}}{\#\ \text{Beams}}\right]$$

For deck-on-beam bridges that fall outside the LRFD Table 4.6.2.2.2b-1 and 4.6.2.2.2.d-1 "Range of Applicability", a 3D model may be used to determine deflections.

Table 3.4.1.1
Maximum Unfactored HL-93 Live Load Moments, Shears, and Reactions
Simple Spans, One Lane, w/o Dynamic Load Allowance or Multiple Presence Factor

Span (ft)	Moments				Shears and End Reactions		
	Truck (kip-ft)	Tandem (kip-ft)	Lane (kip-ft)	Span Pt. (%)	Truck (kip)	Tandem (kip)	Lane (kip)
1	8.0	6.3	0.1	0.50	32.0	25.0	0.3
2	16.0	12.5	0.3	0.50	32.0	25.0	0.6
3	24.0	18.8	0.7	0.50	32.0	25.0	1.0
4	32.0	25.0	1.3	0.50	32.0	25.0	1.3
5	40.0	31.3	2.0	0.50	32.0	30.0	1.6
6	48.0	37.5	2.9	0.50	32.0	33.3	1.9
7	56.0	43.8	3.9	0.50	32.0	35.7	2.2
8	64.0	50.0	5.1	0.50	32.0	37.5	2.6
9	72.0	62.5	6.5	0.50	32.0	38.9	2.9
10	80.0	75.0	8.0	0.50	32.0	40.0	3.2
11	84.5	92.0	9.3	0.40	32.0	40.9	3.5
12	92.2	104.0	11.1	0.40	32.0	41.7	3.8
13	103.0	115.9	13.4	0.45	32.0	52.3	4.2
14	110.9	128.3	15.5	0.45	32.0	52.9	4.5
15	118.8	140.6	17.8	0.45	34.1	43.3	4.8
16	126.7	153.0	20.3	0.45	36.0	43.8	5.1
17	134.6	165.4	22.9	0.45	37.6	44.1	5.4
18	142.6	177.8	25.7	0.45	39.1	44.4	5.8
19	150.5	190.1	28.6	0.45	40.4	44.7	6.1
20	158.4	202.5	31.7	0.45	41.6	45.0	6.4
21	166.3	214.9	34.9	0.45	42.7	45.2	6.7
22	174.2	227.3	38.3	0.45	43.6	45.5	7.0
23	182.2	239.6	41.9	0.45	44.5	45.7	7.4
24	190.1	252.0	45.6	0.45	45.3	45.8	7.7
25	198.0	264.4	49.5	0.45	46.1	46.0	8.0
26	210.2	276.8	53.5	0.45	46.8	46.2	8.3
27	226.1	289.1	57.7	0.45	47.4	46.3	8.6
28	241.9	301.5	62.1	0.45	48.0	46.4	9.0
29	257.8	313.9	66.6	0.45	48.8	46.6	9.3
30	273.6	326.3	71.3	0.45	49.6	46.7	9.6
31	289.4	338.6	76.1	0.45	50.3	46.8	9.9
32	307.0	351.0	81.1	0.45	51.0	46.9	10.2
33	324.9	363.4	86.2	0.45	51.6	47.0	10.6
34	332.0	375.0	92.5	0.50	52.2	47.1	10.9
35	350.0	387.5	98.0	0.50	52.8	47.1	11.2
36	368.0	400.0	103.7	0.50	53.3	47.2	11.5
37	386.0	412.5	109.5	0.50	53.8	47.3	11.8
38	404.0	425.0	115.5	0.50	54.3	47.4	12.2
39	422.0	437.5	121.7	0.50	54.8	47.4	12.5
40	440.0	450.0	128.0	0.50	55.2	47.5	12.8

Table 3.4.1.2
Maximum Unfactored HL-93 Live Load Moments, Shears, and Reactions
Simple Spans, One Lane, w/o Dynamic Load Allowance or Multiple Presence Factor

Span (ft)	Moments				Shears and End Reactions		
	Truck (kip-ft)	Tandem (kip-ft)	Lane (kip-ft)	Span Pt. (%)	Truck (kip)	Tandem (kip)	Lane (kip)
42	485.2	474.8	139.7	0.45	56.0	47.6	13.4
44	520.9	499.5	153.3	0.45	56.7	47.7	14.1
46	556.5	524.3	167.6	0.45	57.4	47.8	14.7
48	592.2	549.0	182.5	0.45	58.0	47.9	15.4
50	627.8	573.8	198.0	0.45	58.6	48.0	16.0
52	663.4	598.5	214.2	0.45	59.1	48.1	16.6
54	699.1	623.3	230.9	0.45	59.6	48.1	17.3
56	734.7	648.0	248.4	0.45	60.0	48.2	17.9
58	770.4	672.8	266.4	0.45	60.4	48.3	18.6
60	806.0	697.5	285.1	0.45	60.8	48.3	19.2
62	841.6	722.3	304.4	0.45	61.2	48.4	19.8
64	877.3	747.0	324.4	0.45	61.5	48.4	20.5
66	912.9	771.8	345.0	0.45	61.8	48.5	21.1
68	948.6	796.5	366.2	0.45	62.1	48.5	21.8
70	984.2	821.3	388.1	0.45	62.4	48.6	22.4
75	1070.0	887.5	450.0	0.50	63.0	48.7	24.0
80	1160.0	950.0	512.0	0.50	63.6	48.8	25.6
85	1250.0	1012.5	578.0	0.50	64.1	48.8	27.2
90	1340.0	1075.0	648.0	0.50	64.5	48.9	28.8
95	1430.0	1137.5	722.0	0.50	64.9	48.9	30.4
100	1520.0	1200.0	800.0	0.50	65.3	49.0	32.0
110	1700.0	1325.0	968.0	0.50	65.9	49.1	35.2
120	1880.0	1450.0	1152.0	0.50	66.4	49.2	38.4
130	2060.0	1575.0	1352.0	0.50	66.8	49.2	41.6
140	2240.0	1700.0	1568.0	0.50	67.2	49.3	44.8
150	2420.0	1825.0	1800.0	0.50	67.5	49.3	48.0
160	2600.0	1950.0	2048.0	0.50	67.8	49.4	51.2
170	2780.0	2075.0	2312.0	0.50	68.0	49.4	54.4
180	2960.0	2200.0	2592.0	0.50	68.3	49.4	57.6
190	3140.0	2325.0	2888.0	0.50	68.5	49.5	60.8
200	3320.0	2450.0	3200.0	0.50	68.6	49.5	64.0

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panels, and sound walls, whose load acts entirely outside the exterior beam, should be assumed to be carried by the exterior beam.

4.2.2 Live Load Distribution

Equations and tables for live load distribution factors are provided in the LRFD Specifications.

4.2.2.1 Steel and Prestressed Concrete Beams

[4.6.2.2]

For typical beam bridges, use the live load distribution factor (LLDF) formulas provided in the LRFD Specifications for interior beam flexure (single lane, multiple lanes, and fatigue), and interior beam shear (single lane, multiple lanes, and fatigue). For exterior beams, use the lever rule and LLDF formulas to determine the amount of live load carried by the exterior beam. In addition, use the rigid cross section equation (LRFD C4.6.2.2.2d-1) for steel beam bridges. The number of diaphragms/cross frames found in steel beam bridges makes rigid cross-section rotation and deflection a valid behavior to consider. Use of the rigid cross section equation is not required for design of precast prestressed concrete exterior beams.

Unlike the Standard Specifications, the LRFD live load distribution factors (LLDF) for beam bridges are dependent on the stiffness of the components that make up the cross section [LRFD Equation 4.6.2.2.1-1]. Theoretically, the distribution factor changes for each change in cross section (at flange plate changes in plate girders, for example). However, this is more refinement than is necessary. For simple span structures a single LLDF (computed at midspan) may be used. For continuous structures, a single LLDF may be used for each positive moment region and for each negative moment region, with the moment regions defined by the dead load contraflexure points. For bridges with consistent geometry (same number of beam lines in each span, etc.) the largest positive moment LLDF may be used for all positive moment locations. Similarly, the largest negative moment LLDF may be used for all negative moment regions. Also note that for continuous structures, use the span length "L" as defined by LRFD Table 4.6.2.2.1-2 for LLDF calculations. ||

For skewed superstructures:

- *[4.6.2.2.2e]* Apply the live load distribution reduction factor for moment per LRFD Article 4.6.2.2.2e.
- *[4.6.2.2.3c]* Apply the live load distribution correction factor for shear to all beams and throughout the entire beam length.

4.2.2.2 Slab Spans and Timber Decks [4.6.2.3]

Design concrete slabs and timber decks using a one foot wide longitudinal strip. The LRFD Specifications provide equations for live load distribution factors (LLDF) that result in equivalent strip widths, E, that are assumed to carry one lane of traffic. Convert the equivalent strip width to a live load distribution factor for the unit strip by taking the reciprocal of the width.

$$LLDF = \frac{1}{E}$$

4.2.3 Sidewalk Pedestrian Live Load [3.6.1.6]

Unlike the Standard Specifications, no reduction in sidewalk pedestrian live load intensity based on span length and sidewalk width is provided in the LRFD Specifications.

1) Consider two loading cases when designing a beam bridge with a sidewalk: Use a pedestrian live load on the sidewalk equal to 0.075 ksf, and apply it in conjunction with a vehicular live load in the traffic lanes adjacent to the sidewalk. Use the lever rule to determine distribution of sidewalk dead load, pedestrian live load, and vehicular live load to outer beams.

2) Place vehicular live load on the sidewalk and in adjacent traffic lanes with no pedestrian live load on the sidewalk. For this load case, assume dead load, including sidewalk, is carried equally by all beams.

4.3 Load Rating

The bridge load rating determines the safe load carrying capacity. Ratings are calculated for a new bridge and are recalculated throughout the bridge’s life as changes occur.

Unlike design, where only one benchmark or level of safety is used, two different levels have historically been used for load rating. These rating levels are referred to as the “inventory rating” and “operating rating”. The inventory rating corresponds to the factors of safety or levels of reliability associated with new bridge designs. The operating rating corresponds to slightly relaxed safety factors or reliability indices and is used for infrequent, regulated loads. Calculations for overload permit evaluations and for bridge weight postings are made at the operating level.

The Design Data block on the front sheet of a set of bridge plans should contain the LRFR HL-93 operating rating factor for the bridge.

5. CONCRETE STRUCTURES

Reinforced and prestressed concrete are used extensively in bridge projects. In addition to general design guidance and information on detailing practices, this section contains three design examples: a three-span reinforced concrete slab superstructure, a 63 inch pretensioned I-beam, and a three-span post-tensioned concrete slab superstructure.

5.1 Materials

For most projects, conventional materials should be specified. Standard materials are described in two locations: *MnDOT Standard Specifications for Construction* (MnDOT Spec.) and *Bridge Special Provisions*.

If multiple types of concrete or reinforcement are to be used in a project, it is the designer's responsibility to clearly show on the plans the amount of each material to be provided and where it is to be placed.

5.1.1 Concrete

MnDOT Spec. 2461 identifies and describes concrete mix types. Based on their strength, location of application, and durability properties, different mixes are used for various structural concrete components. Table 5.1.1.1 identifies the standard MnDOT concrete mix types to be used for different bridge components.

The four or five characters used to identify a concrete mix provide information on the properties of the mix. The first character designates the type of concrete (with or without air entrainment requirements). The second character identifies the grade of concrete. Each letter is associated with a different cement-void ratio. The third character in the label is the upper limit for the slump in inches. The fourth character identifies the coarse aggregate gradation. The fifth character, if present, identifies the type of coarse aggregate to be used. Note that there are two exceptions to the above: job mixes (JM) for box girders, and high performance concrete (HPC) mixes for bridge decks and slabs.

For HPC mixes, the first and second characters follow the description above. For monolithically poured decks, these are followed by either "HPC-M" or "LCHPC-M" (where the LC designates low cement). For decks that will receive a separate wearing course, these are followed by either "HPC-S" or "LCHPC-S" (where the LC designates low cement). For job mixes, the first character designates the type of concrete as above, but is followed by "JM" for mixes that will be determined by the Contractor.

In general, the standard concrete design strength is 4 ksi, and air entrained concretes are to be used for components located above footings and pile caps to enhance durability.

Table 5.1.1.1 Design Concrete Mix Summary

Location/Element	MnDOT Concrete Mix Designation	Design Compressive Strength (ksi)	Maximum Aggregate Size (in)
Cofferdam seals	1X62	5.0	1
Cast-in-place concrete piles and spread footing leveling pads	1P62	3.0	2
Drilled shafts	1X62 3X62	5.0 5.0	1 1
Footings and pile caps	1G52	4.0	1 ½ *
Abutment stems, wingwalls, cast-in-place wall stems, pier columns, and pier caps	3B52	4.0	1 ½ *
Integral abutment diaphragms and pier continuity diaphragms	Same mix as used in deck	4.0	1
Pretensioned superstructures	1W82 or 3W82	5.0 – 9.0 at final 4.5 – 7.5 at initial	1
Cast-in-place and precast box girders	3JM	6.0 or higher	1
Monolithic decks and slabs	3YHPC-M, 3YLCHPC-M or 3Y42-M	4.0	1
Decks and slabs that will receive a 2 inch concrete wearing course	3YHPC-S, 3YLCHPC-S or 3Y42-S	4.0	1
Barriers, parapets, medians, and sidewalks	3S52	4.0	1
Concrete wearing course	3U17A	4.0	$^{5}/_{8}$
MSE wall panels, PMBW blocks, and noisewall panels	3Y82	4.0	1
Precast box culverts, arches, and 3-sided structures	3W82	5.0 or higher	1*

* For determination of s_{xe} per LRFD 5.8.3.4.2, use max aggregate size a_g = ¾”

Reinforced Concrete Sections

Base concrete modulus of elasticity computations on a unit weight of 0.145 kcf. Use a unit weight of 0.150 kcf for dead load calculations.

For structural modeling (determining design forces and deflections), use gross section properties or effective section properties. For redundant structures with redundant and nonprismatic members, model with nonprismatic elements.

[5.4.2.4-1]

For reinforced concrete elements, use: $E_c = 33{,}000 \cdot K_1 \cdot w_c^{1.5} \cdot \sqrt{f'_c}$

For checks based on strength (design of reinforcement, maximum reinforcement), use conventional strength methods (reinforcement yielding, Whitney equivalent stress block, etc.).

The weight of spiral reinforcement on a per foot basis is provided in Table 5.2.2.3. The standard spiral reinforcement is $^1/_2$ inch diameter with a 3 inch pitch. When selecting the size of round columns, use outside dimensions that are consistent with cover requirements and standard spiral outside diameters.

Figure 5.2.2.1 through 5.2.2.5 contain development length (Class A lap) and tension lap splice design tables for epoxy coated, plain uncoated, and stainless steel reinforcement bars. Knowing the bar size, location, concrete cover, bar spacing, and class of splice, designers can readily find the appropriate lap length. The tables are based on 4 ksi concrete.

Figure 5.2.2.6 contains development length tables for bars with standard hooks. Values are provided for epoxy coated, plain uncoated, and stainless steel reinforcement bars. Standard hook dimensions are also included.

Figure 5.2.2.7 contains graphics that illustrate acceptable methods for anchoring or lapping stirrup reinforcement. Open stirrups must have the "open" end anchored in the compression side of the member. This anchorage consists of development of the bar or hook prior to reaching a depth of $^d/_2$ or placing the hooks around longitudinal reinforcement. Detail closed double stirrups with a Class B lap. Also included in Figure 5.2.2.7 are stirrup and tie hook dimensions and a table showing minimum horizontal bar spacings for various concrete mixes.

Table 5.2.2.3
Weight of Spiral Reinforcement

O.D. SPIRAL (in)	WEIGHTS IN POUNDS PER FOOT OF HEIGHT			
	3/8" DIA. ROD		1/2" DIA. ROD	
	6" PITCH (lb/ft)	F (lb)	3" PITCH (lb/ft)	F (lb)
24	4.72	7.1	16.79	12.60
26	5.12	7.7	18.19	13.65
28	5.51	8.3	19.59	14.70
30	5.91	8.9	20.99	15.75
32	6.30	9.5	22.38	16.80
34	6.69	10.1	23.78	17.85
36	7.09	10.7	25.18	18.90
38	7.48	11.2	26.58	20.00
40	7.87	11.8	27.98	21.00
42	8.27	12.4	29.38	22.00
44	8.66	13.0	30.78	23.10
46	9.06	13.6	32.18	24.10
48	9.45	14.2	33.58	25.20
50	9.84	14.8	34.98	26.20
52	10.24	15.4	36.38	27.30
54	10.63	15.9	37.77	28.30
56	11.02	16.5	39.17	29.40
58	11.42	17.1	40.57	30.40
60	11.81	17.7	41.97	31.50
62	12.21	18.3	43.37	32.50
64	12.60	18.9	44.77	33.60
66	12.99	19.5	46.17	34.60
68	13.39	20.1	47.57	35.70

For more complete coverage, see *CRSI Design Handbook*.

Total weight = (wt. per ft x height) + F

F = weight to add for finishing
(this includes 1 1/2 turns at the top and 1 1/2 turns at the bottom of spiral)

For additional information see MnDOT 2472 and AASHTO LRFD 5.10.6.2

TENSION LAP SPLICES FOR EPOXY COATED BARS WITH >12″ CONCRETE CAST BELOW

f_y=60 ksi f_c'=4 ksi

Conc. Cover	Bar Size	Reinforcement Bar Spacing															
		4″		5″		5 1/2″		6″		6 1/2″		7″		7 1/2″		≥ 8″	
		Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B
2"	3	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"
	4	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"
	5	2'-7"	3'-4"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"
	6	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"
	7	3'-11"	5'-1"	3'-7"	4'-8"	3'-7"	4'-8"	3'-7"	4'-8"	3'-7"	4'-8"	3'-7"	4'-8"	3'-7"	4'-8"	3'-7"	4'-8"
	8	5'-2"	6'-8"	4'-1"	5'-4"	4'-1"	5'-4"	4'-1"	5'-4"	4'-1"	5'-4"	4'-1"	5'-4"	4'-1"	5'-4"	4'-1"	5'-4"
	9	6'-6"	8'-6"	5'-3"	6'-9"	5'-1"	6'-7"	5'-1"	6'-7"	5'-1"	6'-7"	5'-1"	6'-7"	5'-1"	6'-7"	5'-1"	6'-7"
	10	8'-3"	10'-9"	6'-7"	8'-7"	6'-3"	8'-2"	6'-3"	8'-2"	6'-3"	8'-2"	6'-3"	8'-2"	6'-3"	8'-2"	6'-3"	8'-2"
	11	10'-2"	13'-3"	8'-2"	10'-7"	7'-6"	9'-9"	7'-6"	9'-9"	7'-6"	9'-9"	7'-6"	9'-9"	7'-6"	9'-9"	7'-6"	9'-9"
	14	N/A	N/A	11'-9"	15'-3"	10'-8"	13'-10"	10'-4"	13'-5"	10'-4"	13'-5"	10'-4"	13'-5"	10'-4"	13'-5"	10'-4"	13'-5"
$2\frac{3"}{8}$	3	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"
	4	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"
	5	2'-7"	3'-4"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"
	6	3'-1"	4'-0"	3'-1"	4'-0"	2'-10"	3'-8"	2'-10"	3'-8"	2'-10"	3'-8"	2'-10"	3'-8"	2'-10"	3'-8"	2'-10"	3'-8"
	7	3'-11"	5'-1"	3'-7"	4'-8"	3'-7"	4'-8"	3'-7"	4'-8"	3'-7"	4'-8"	3'-7"	4'-8"	3'-7"	4'-8"	3'-7"	4'-8"
	8	5'-2"	6'-8"	4'-1"	5'-4"	4'-1"	5'-4"	4'-1"	5'-4"	4'-1"	5'-4"	4'-1"	5'-4"	4'-1"	5'-4"	4'-1"	5'-4"
	9	6'-6"	8'-6"	5'-3"	6'-9"	4'-9"	6'-2"	4'-8"	6'-0"	4'-8"	6'-0"	4'-8"	6'-0"	4'-8"	6'-0"	4'-8"	6'-0"
	10	8'-3"	10'-9"	6'-7"	8'-7"	6'-0"	7'-10"	5'-6"	7'-2"	5'-6"	7'-2"	5'-6"	7'-2"	5'-6"	7'-2"	5'-6"	7'-2"
	11	10'-2"	13'-3"	8'-2"	10'-7"	7'-5"	9'-8"	6'-10"	8'-10"	6'-8"	8'-7"	6'-8"	8'-7"	6'-8"	8'-7"	6'-8"	8'-7"
	14	N/A	N/A	11'-9"	15'-3"	10'-8"	13'-10"	9'-9"	12'-9"	9'-1"	11'-10"	9'-1"	11'-10"	9'-1"	11'-10"	9'-1"	11'-10"
≥ 3″	3	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"	1'-5"	1'-10"
	4	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"
	5	2'-7"	3'-4"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"
	6	3'-1"	4'-0"	3'-1"	4'-0"	2'-10"	3'-8"	2'-10"	3'-8"	2'-10"	3'-8"	2'-10"	3'-8"	2'-10"	3'-8"	2'-10"	3'-8"
	7	3'-11"	5'-1"	3'-7"	4'-8"	3'-7"	4'-8"	3'-7"	4'-8"	3'-4"	4'-4"	3'-4"	4'-4"	3'-4"	4'-4"	3'-4"	4'-4"
	8	5'-2"	6'-8"	4'-1"	5'-4"	4'-1"	5'-4"	4'-1"	5'-4"	4'-1"	5'-4"	3'-9"	4'-11"	3'-9"	4'-11"	3'-9"	4'-11"
	9	6'-6"	8'-6"	5'-3"	6'-9"	4'-9"	6'-2"	4'-8"	6'-0"	4'-8"	6'-0"	4'-8"	6'-0"	4'-8"	6'-0"	4'-8"	6'-0"
	10	8'-3"	10'-9"	6'-7"	8'-7"	6'-0"	7'-10"	5'-6"	7'-2"	5'-3"	6'-9"	5'-3"	6'-9"	5'-3"	6'-9"	5'-3"	6'-9"
	11	10'-2"	13'-3"	8'-2"	10'-7"	7'-5"	9'-8"	6'-10"	8'-10"	6'-3"	8'-2"	5'-10"	7'-7"	5'-10"	7'-6"	5'-10"	7'-6"
	14	N/A	N/A	11'-9"	15'-3"	10'-8"	13'-10"	9'-9"	12'-9"	9'-0"	11'-9"	8'-5"	10'-11"	7'-10"	10'-2"	7'-8"	9'-11"

Table includes modification factors for reinforcement location, epoxy coating, normal weight concrete, and reinforcement confinement as specified in AASHTO Articles 5.11.2.1.2 and 5.11.2.1.3. Reinforcement confinement is conservatively calculated by taking transverse reinforcement index as 0. Excess reinforcement factor is taken conservatively as 1.0. Tension lap splice lengths are based on AASHTO Article 5.11.5.3.1. Concrete cover is defined as the cover to the bar being considered. For concrete cover or bar spacing that falls between table values, conservatively use lap splice shown in the table for smaller concrete cover or bar spacing.

TENSION LAP SPLICES	Percent of A_s spliced within required lap length	
$A_{s,\ provided}/A_{s,\ required}$	≤ 50	> 50
≥ 2	Class A	Class B
< 2	Class B	Class B

Where: $A_{s,\ provided}$ = Area of reinforcement provided and $A_{s,\ required}$ = Area of reinforcement required by analysis

Figure 5.2.2.1
Reinforcement Data

TENSION LAP SPLICES FOR EPOXY COATED BARS WITH ≤ 12″ CONCRETE CAST BELOW

f_y=60 ksi f_c'=4 ksi

Conc. Cover	Bar Size	**Reinforcement Bar Spacing**															
		4″		5″		5 1/2″		6″		6 1/2″		7″		7 1/2″		≥ 8″	
		Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B
1″	**3**	**1'-5"**	**1'-10"**	**1'-5"**	**1'-10"**	**1'-5"**	**1'-10"**	**1'-5"**	**1'-10"**	**1'-5"**	**1'-10"**	**1'-5"**	**1'-10"**	**1'-5"**	**1'-10"**	**1'-5"**	**1'-10"**
	4	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"
	5	**2'-9"**	**3'-6"**	**2'-9"**	**3'-6"**	**2'-9"**	**3'-6"**	**2'-9"**	**3'-6"**	**2'-9"**	**3'-6"**	**2'-9"**	**3'-6"**	**2'-9"**	**3'-6"**	**2'-9"**	**3'-6"**
	6	3'-9"	4'-10"	3'-9"	4'-10"	3'-9"	4'-10"	3'-9"	4'-10"	3'-9"	4'-10"	3'-9"	4'-10"	3'-9"	4'-10"	3'-9"	4'-10"
	7	**4'-10"**	**6'-3"**	**4'-10"**	**6'-3"**	**4'-10"**	**6'-3"**	**4'-10"**	**6'-3"**	**4'-10"**	**6'-3"**	**4'-10"**	**6'-3"**	**4'-10"**	**6'-3"**	**4'-10"**	**6'-3"**
	8	6'-0"	7'-10"	6'-0"	7'-10"	6'-0"	7'-10"	6'-0"	7'-10"	6'-0"	7'-10"	6'-0"	7'-10"	6'-0"	7'-10"	6'-0"	7'-10"
	9	**7'-4"**	**9'-7"**	**7'-4"**	**9'-7"**	**7'-4"**	**9'-7"**	**7'-4"**	**9'-7"**	**7'-4"**	**9'-7"**	**7'-4"**	**9'-7"**	**7'-4"**	**9'-7"**	**7'-4"**	**9'-7"**
	10	8'-11"	11'-7"	8'-11"	11'-7"	8'-11"	11'-7"	8'-11"	11'-7"	8'-11"	11'-7"	8'-11"	11'-7"	8'-11"	11'-7"	8'-11"	11'-7"
	11	**10'-6"**	**13'-8"**	**10'-6"**	**13'-8"**	**10'-6"**	**13'-8"**	**10'-6"**	**13'-8"**	**10'-6"**	**13'-8"**	**10'-6"**	**13'-8"**	**10'-6"**	**13'-8"**	**10'-6"**	**13'-8"**
	14	N/A	N/A	14'-0"	18'-2"	14'-0"	18'-2"	14'-0"	18'-2"	14'-0"	18'-2"	14'-0"	18'-2"	14'-0"	18'-2"	14'-0"	18'-2"
$1\frac{1"}{2}$	**3**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**
	4	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"
	5	**2'-3"**	**3'-0"**	**2'-3"**	**3'-0"**	**2'-3"**	**3'-0"**	**2'-3"**	**3'-0"**	**2'-3"**	**3'-0"**	**2'-3"**	**3'-0"**	**2'-3"**	**3'-0"**	**2'-3"**	**3'-0"**
	6	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"
	7	**3'-7"**	**4'-8"**	**3'-7"**	**4'-8"**	**3'-7"**	**4'-8"**	**3'-7"**	**4'-8"**	**3'-7"**	**4'-8"**	**3'-7"**	**4'-8"**	**3'-7"**	**4'-8"**	**3'-7"**	**4'-8"**
	8	4'-6"	5'-11"	4'-6"	5'-11"	4'-6"	5'-11"	4'-6"	5'-11"	4'-6"	5'-11"	4'-6"	5'-11"	4'-6"	5'-11"	4'-6"	5'-11"
	9	**5'-9"**	**7'-6"**	**5'-7"**	**7'-3"**	**5'-7"**	**7'-3"**	**5'-7"**	**7'-3"**	**5'-7"**	**7'-3"**	**5'-7"**	**7'-3"**	**5'-7"**	**7'-3"**	**5'-7"**	**7'-3"**
	10	7'-4"	9'-6"	6'-10"	8'-11"	6'-10"	8'-11"	6'-10"	8'-11"	6'-10"	8'-11"	6'-10"	8'-11"	6'-10"	8'-11"	6'-10"	8'-11"
	11	**9'-0"**	**11'-8"**	**8'-2"**	**10'-7"**	**8'-2"**	**10'-7"**	**8'-2"**	**10'-7"**	**8'-2"**	**10'-7"**	**8'-2"**	**10'-7"**	**8'-2"**	**10'-7"**	**8'-2"**	**10'-7"**
	14	N/A	N/A	11'-0"	14'-4"	11'-0"	14'-4"	11'-0"	14'-4"	11'-0"	14'-4"	11'-0"	14'-4"	11'-0"	14'-4"	11'-0"	14'-4"
2″	**3**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**
	4	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"
	5	**2'-3"**	**3'-0"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**
	6	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"
	7	**3'-6"**	**4'-6"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**
	8	4'-6"	5'-11"	3'-8"	4'-9"	3'-8"	4'-9"	3'-8"	4'-9"	3'-8"	4'-9"	3'-8"	4'-9"	3'-8"	4'-9"	3'-8"	4'-9"
	9	**5'-9"**	**7'-6"**	**4'-7"**	**6'-0"**	**4'-6"**	**5'-10"**	**4'-6"**	**5'-10"**	**4'-6"**	**5'-10"**	**4'-6"**	**5'-10"**	**4'-6"**	**5'-10"**	**4'-6"**	**5'-10"**
	10	7'-4"	9'-6"	5'-10"	7'-7"	5'-7"	7'-2"	5'-7"	7'-2"	5'-7"	7'-2"	5'-7"	7'-2"	5'-7"	7'-2"	5'-7"	7'-2"
	11	**9'-0"**	**11'-8"**	**7'-2"**	**9'-4"**	**6'-8"**	**8'-8"**	**6'-8"**	**8'-8"**	**6'-8"**	**8'-8"**	**6'-8"**	**8'-8"**	**6'-8"**	**8'-8"**	**6'-8"**	**8'-8"**
	14	N/A	N/A	10'-4"	13'-5"	9'-5"	12'-3"	9'-1"	11'-10"	9'-1"	11'-10"	9'-1"	11'-10"	9'-1"	11'-10"	9'-1"	11'-10"
$2\frac{3"}{8}$	**3**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**
	4	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"
	5	**2'-3"**	**3'-0"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**
	6	2'-9"	3'-7"	2'-9"	3'-7"	2'-2"	2'-10"	2'-2"	2'-10"	2'-2"	2'-10"	2'-2"	2'-10"	2'-2"	2'-10"	2'-2"	2'-10"
	7	**3'-6"**	**4'-6"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**
	8	4'-6"	5'-11"	3'-8"	4'-9"	3'-8"	4'-9"	3'-8"	4'-9"	3'-8"	4'-9"	3'-8"	4'-9"	3'-8"	4'-9"	3'-8"	4'-9"
	9	**5'-9"**	**7'-6"**	**4'-7"**	**6'-0"**	**4'-2"**	**5'-5"**	**4'-1"**	**5'-4"**	**4'-1"**	**5'-4"**	**4'-1"**	**5'-4"**	**4'-1"**	**5'-4"**	**4'-1"**	**5'-4"**
	10	7'-4"	9'-6"	5'-10"	7'-7"	5'-4"	6'-11"	4'-11"	6'-4"	4'-10"	6'-4"	4'-10"	6'-4"	4'-10"	6'-4"	4'-10"	6'-4"
	11	**9'-0"**	**11'-8"**	**7'-2"**	**9'-4"**	**6'-7"**	**8'-6"**	**6'-0"**	**7'-10"**	**5'-10"**	**7'-7"**	**5'-10"**	**7'-7"**	**5'-10"**	**7'-7"**	**5'-10"**	**7'-7"**
	14	N/A	N/A	10'-4"	13'-5"	9'-5"	12'-3"	8'-8"	11'-3"	8'-1"	10'-5"	8'-1"	10'-5"	8'-1"	10'-5"	8'-1"	10'-5"
≥ 3″	**3**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**	**1'-1"**	**1'-5"**
	4	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"
	5	**2'-3"**	**3'-0"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**	**1'-10"**	**2'-5"**
	6	2'-9"	3'-7"	2'-9"	3'-7"	2'-2"	2'-10"	2'-2"	2'-10"	2'-2"	2'-10"	2'-2"	2'-10"	2'-2"	2'-10"	2'-2"	2'-10"
	7	**3'-6"**	**4'-6"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**	**3'-2"**	**4'-2"**	**2'-7"**	**3'-4"**	**2'-7"**	**3'-4"**	**2'-7"**	**3'-4"**	**2'-7"**	**3'-4"**
	8	4'-6"	5'-11"	3'-8"	4'-9"	3'-8"	4'-9"	3'-8"	4'-9"	3'-8"	4'-9"	2'-11"	3'-9"	2'-11"	3'-9"	2'-11"	3'-9"
	9	**5'-9"**	**7'-6"**	**4'-7"**	**6'-0"**	**4'-2"**	**5'-5"**	**4'-1"**	**5'-4"**	**4'-1"**	**5'-4"**	**4'-1"**	**5'-4"**	**4'-1"**	**5'-4"**	**4'-1"**	**5'-4"**
	10	7'-4"	9'-6"	5'-10"	7'-7"	5'-4"	6'-11"	4'-11"	6'-4"	4'-7"	6'-0"	4'-7"	6'-0"	4'-7"	6'-0"	4'-7"	6'-0"
	11	**9'-0"**	**11'-8"**	**7'-2"**	**9'-4"**	**6'-7"**	**8'-6"**	**6'-0"**	**7'-10"**	**5'-7"**	**7'-2"**	**5'-2"**	**6'-8"**	**5'-1"**	**6'-8"**	**5'-1"**	**6'-8"**
	14	N/A	N/A	10'-4"	13'-5"	9'-5"	12'-3"	8'-8"	11'-3"	8'-0"	10'-4"	7'-5"	9'-7"	6'-11"	9'-0"	6'-9"	8'-9"

Table includes modification factors for reinforcement location, epoxy coating, normal weight concrete, and reinforcement confinement as specified in AASHTO Articles 5.11.2.1.2 and 5.11.2.1.3. Reinforcement confinement is conservatively calculated by taking transverse reinforcement index as 0. Excess reinforcement factor is taken conservatively as 1.0. Tension lap splice lengths are based on AASHTO Article 5.11.5.3.1. Concrete cover is defined as the cover to the bar being considered. For concrete cover or bar spacing that falls between table values, conservatively use lap splice shown in the table for smaller concrete cover or bar spacing.

TENSION LAP SPLICES	Percent of A_s spliced within required lap length	
$A_{s,\ provided}/A_{s,\ required}$	≤ 50	> 50
≥ 2	Class A	Class B
< 2	Class B	Class B

Where: $A_{s,\ provided}$ = Area of reinforcement provided and $A_{s,\ required}$ = Area of reinforcement required by analysis

Figure 5.2.2.2
Reinforcement Data

TENSION LAP SPLICES FOR PLAIN UNCOATED BARS WITH >12" CONCRETE CAST BELOW

f_y=60 ksi f_c'=4 ksi

Conc. Cover	Bar Size	Reinforcement Spacing															
		4"		5"		5 1/2"		6"		6 1/2"		7"		7 1/2"		≥ 8"	
		Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B
2"	3	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"
	4	1'-7"	2'-1"	1'-7"	2'-1"	1'-7"	2'-1"	1'-7"	2'-1"	1'-7"	2'-1"	1'-7"	2'-1"	1'-7"	2'-1"	1'-7"	2'-1"
	5	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"
	6	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"
	7	3'-0"	3'-11"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"
	8	3'-11"	5'-1"	3'-2"	4'-1"	3'-2"	4'-1"	3'-2"	4'-1"	3'-2"	4'-1"	3'-2"	4'-1"	3'-2"	4'-1"	3'-2"	4'-1"
	9	5'-0"	6'-6"	4'-0"	5'-2"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"
	10	6'-4"	8'-3"	5'-1"	6'-7"	4'-10"	6'-3"	4'-10"	6'-3"	4'-10"	6'-3"	4'-10"	6'-3"	4'-10"	6'-3"	4'-10"	6'-3"
	11	7'-10"	10'-1"	6'-3"	8'-1"	5'-9"	7'-6"	5'-9"	7'-6"	5'-9"	7'-6"	5'-9"	7'-6"	5'-9"	7'-6"	5'-9"	7'-6"
	14	N/A	N/A	9'-0"	11'-8"	8'-2"	10'-7"	7'-11"	10'-3"	7'-11"	10'-3"	7'-11"	10'-3"	7'-11"	10'-3"	7'-11"	10'-3"
≥ 3"	3	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"
	4	1'-7"	2'-1"	1'-7"	2'-1"	1'-7"	2'-1"	1'-7"	2'-1"	1'-7"	2'-1"	1'-7"	2'-1"	1'-7"	2'-1"	1'-7"	2'-1"
	5	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"
	6	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"	2'-5"	3'-1"
	7	3'-0"	3'-11"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"
	8	3'-11"	5'-1"	3'-2"	4'-1"	3'-2"	4'-1"	3'-2"	4'-1"	3'-2"	4'-1"	3'-2"	4'-1"	3'-2"	4'-1"	3'-2"	4'-1"
	9	5'-0"	6'-6"	4'-0"	5'-2"	3'-8"	4'-9"	3'-7"	4'-7"	3'-7"	4'-7"	3'-7"	4'-7"	3'-7"	4'-7"	3'-7"	4'-7"
	10	6'-4"	8'-3"	5'-1"	6'-7"	4'-7"	6'-0"	4'-3"	5'-6"	4'-0"	5'-2"	4'-0"	5'-2"	4'-0"	5'-2"	4'-0"	5'-2"
	11	7'-10"	10'-1"	6'-3"	8'-1"	5'-8"	7'-4"	5'-3"	6'-9"	4'-10"	6'-3"	4'-6"	5'-10"	4'-5"	5'-9"	4'-5"	5'-9"
	14	N/A	N/A	9'-0"	11'-8"	8'-2"	10'-7"	7'-6"	9'-9"	6'-11"	9'-0"	6'-5"	8'-4"	6'-0"	7'-10"	5'-10"	7'-7"

TENSION LAP SPLICES FOR PLAIN UNCOATED BARS WITH ≤ 12" CONCRETE CAST BELOW

f_y=60 ksi f_c'=4 ksi

Conc. Cover	Bar Size	Reinforcement Spacing															
		4"		5"		5 1/2"		6"		6 1/2"		7"		7 1/2"		≥ 8"	
		Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B
2"	3	11"	1'-3"	11"	1'-3"	11"	1'-3"	11"	1'-3"	11"	1'-3"	11"	1'-3"	11"	1'-3"	11"	1'-3"
	4	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"
	5	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"
	6	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"
	7	2'-4"	3'-0"	2'-2"	2'-9"	2'-2"	2'-9"	2'-2"	2'-9"	2'-2"	2'-9"	2'-2"	2'-9"	2'-2"	2'-9"	2'-2"	2'-9"
	8	3'-0"	3'-11"	2'-5"	3'-2"	2'-5"	3'-2"	2'-5"	3'-2"	2'-5"	3'-2"	2'-5"	3'-2"	2'-5"	3'-2"	2'-5"	3'-2"
	9	3'-10"	5'-0"	3'-1"	4'-0"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"
	10	4'-11"	6'-4"	3'-11"	5'-1"	3'-9"	4'-10"	3'-9"	4'-10"	3'-9"	4'-10"	3'-9"	4'-10"	3'-9"	4'-10"	3'-9"	4'-10"
	11	6'-0"	7'-10"	4'-10"	6'-3"	4'-5"	5'-9"	4'-5"	5'-9"	4'-5"	5'-9"	4'-5"	5'-9"	4'-5"	5'-9"	4'-5"	5'-9"
	14	N/A	N/A	6'-11"	9'-0"	6'-4"	8'-2"	6'-1"	7'-11"	6'-1"	7'-11"	6'-1"	7'-11"	6'-1"	7'-11"	6'-1"	7'-11"
≥ 3"	3	11"	1'-3"	11"	1'-3"	11"	1'-3"	11"	1'-3"	11"	1'-3"	11"	1'-3"	11"	1'-3"	11"	1'-3"
	4	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"	1'-3"	1'-7"
	5	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"
	6	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"	1'-10"	2'-5"
	7	2'-4"	3'-0"	2'-2"	2'-9"	2'-2"	2'-9"	2'-2"	2'-9"	2'-2"	2'-9"	2'-2"	2'-9"	2'-2"	2'-9"	2'-2"	2'-9"
	8	3'-0"	3'-11"	2'-5"	3'-2"	2'-5"	3'-2"	2'-5"	3'-2"	2'-5"	3'-2"	2'-5"	3'-2"	2'-5"	3'-2"	2'-5"	3'-2"
	9	3'-10"	5'-0"	3'-1"	4'-0"	2'-10"	3'-8"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"	2'-9"	3'-7"
	10	4'-11"	6'-4"	3'-11"	5'-1"	3'-7"	4'-7"	3'-3"	4'-3"	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"
	11	6'-0"	7'-10"	4'-10"	6'-3"	4'-5"	5'-8"	4'-0"	5'-3"	3'-9"	4'-10"	3'-5"	4'-6"	3'-5"	4'-5"	3'-5"	4'-5"
	14	N/A	N/A	6'-11"	9'-0"	6'-4"	8'-2"	5'-9"	7'-6"	5'-4"	6'-11"	4'-11"	6'-5"	4'-8"	6'-0"	4'-6"	5'-10"

Table includes modification factors for reinforcement location, epoxy coating, normal weight concrete and reinforcement confinement as specified in AASHTO Articles 5.11.2.1.2 and 5.11.2.1.3. Reinforcement confinement is conservatively calculated by taking transverse reinforcement index as 0. Excess reinforcement factor is taken conservatively as 1.0. Tension lap splice lengths are based on AASHTO Article 5.11.5.3.1. Concrete cover is defined as the cover to the bar being considered. For concrete cover or bar spacing that falls between table values, conservatively use lap splice shown in the table for smaller concrete cover or bar spacing.

TENSION LAP SPLICES	Percent of A_s spliced within required lap length	
$A_{s,\ provided}/A_{s,\ required}$	≤ 50	> 50
≥ 2	Class A	Class B
< 2	Class B	Class B

Where: $A_{s,\ provided}$ = Area of reinforcement provided and $A_{s,\ required}$ = Area of reinforcement required by analysis

Figure 5.2.2.3
Reinforcement Data

TENSION LAP SPLICES FOR STAINLESS STEEL BARS WITH >12″ CONCRETE CAST BELOW

f_y=75 ksi f_c'=4 ksi

Conc. Cover	Bar Size	Reinforcement Bar Spacing															
		4″		5″		5 1/2″		6″		6 1/2″		7″		7 1/2″		≥ 8″	
		Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B
2″	3	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"
	4	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"
	5	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"
	6	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"
	7	3'-9"	4'-11"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"
	8	4'-11"	6'-5"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"
	9	6'-3"	8'-1"	5'-0"	6'-6"	4'-11"	6'-4"	4'-11"	6'-4"	4'-11"	6'-4"	4'-11"	6'-4"	4'-11"	6'-4"	4'-11"	6'-4"
	10	7'-11"	10'-3"	6'-4"	8'-3"	6'-0"	7'-10"	6'-0"	7'-10"	6'-0"	7'-10"	6'-0"	7'-10"	6'-0"	7'-10"	6'-0"	7'-10"
	11	9'-9"	12'-8"	7'-10"	10'-1"	7'-2"	9'-4"	7'-2"	9'-4"	7'-2"	9'-4"	7'-2"	9'-4"	7'-2"	9'-4"	7'-2"	9'-4"
	14	N/A	N/A	11'-3"	14'-7"	10'-2"	13'-3"	9'-10"	12'-10"	9'-10"	12'-10"	9'-10"	12'-10"	9'-10"	12'-10"	9'-10"	12'-10"
$2\frac{3"}{8}$	3	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"
	4	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"
	5	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"
	6	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"
	7	3'-9"	4'-11"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"
	8	4'-11"	6'-5"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"
	9	6'-3"	8'-1"	5'-0"	6'-6"	4'-7"	5'-11"	4'-5"	5'-9"	4'-5"	5'-9"	4'-5"	5'-9"	4'-5"	5'-9"	4'-5"	5'-9"
	10	7'-11"	10'-3"	6'-4"	8'-3"	5'-9"	7'-6"	5'-3"	6'-10"	5'-3"	6'-10"	5'-3"	6'-10"	5'-3"	6'-10"	5'-3"	6'-10"
	11	9'-9"	12'-8"	7'-10"	10'-1"	7'-1"	9'-2"	6'-6"	8'-5"	6'-4"	8'-3"	6'-4"	8'-3"	6'-4"	8'-3"	6'-4"	8'-3"
	14	N/A	N/A	11'-3"	14'-7"	10'-2"	13'-3"	9'-4"	12'-2"	8'-9"	11'-4"	8'-9"	11'-4"	8'-9"	11'-4"	8'-9"	11'-4"
≥ 3″	3	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"	1'-6"	1'-11"
	4	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"	2'-0"	2'-7"
	5	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"	2'-6"	3'-3"
	6	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"	3'-0"	3'-10"
	7	3'-9"	4'-11"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"	3'-5"	4'-6"
	8	4'-11"	6'-5"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"	3'-11"	5'-1"
	9	6'-3"	8'-1"	5'-0"	6'-6"	4'-7"	5'-11"	4'-5"	5'-9"	4'-5"	5'-9"	4'-5"	5'-9"	4'-5"	5'-9"	4'-5"	5'-9"
	10	7'-11"	10'-3"	6'-4"	8'-3"	5'-9"	7'-6"	5'-3"	6'-10"	5'-0"	6'-6"	5'-0"	6'-6"	5'-0"	6'-6"	5'-0"	6'-6"
	11	9'-9"	12'-8"	7'-10"	10'-1"	7'-1"	9'-2"	6'-6"	8'-5"	6'-0"	7'-10"	5'-7"	7'-3"	5'-6"	7'-2"	5'-6"	7'-2"
	14	N/A	N/A	11'-3"	14'-7"	10'-2"	13'-3"	9'-4"	12'-2"	8'-8"	11'-3"	8'-0"	10'-5"	7'-6"	9'-9"	7'-4"	9'-6"

Table includes modification factors for reinforcement location, epoxy coating, normal weight concrete and reinforcement confinement as specified in AASHTO Articles 5.11.2.1.2 and 5.11.2.1.3. Reinforcement confinement is conservatively calculated by taking transverse reinforcement index as 0. Excess reinforcement factor is taken conservatively as 1.0. Tension lap splice lengths are based on AASHTO Article 5.11.5.3.1. Concrete cover is defined as the cover to the bar being considered. For concrete cover or bar spacing that falls between table values, conservatively use lap splice shown in the table for smaller concrete cover or bar spacing.

TENSION LAP SPLICES	Percent of A_s spliced within required lap length	
$A_{s,\ provided}/A_{s,\ required}$	≤ 50	> 50
≥ 2	Class A	Class B
< 2	Class B	Class B

Where: $A_{s,\ provided}$ = Area of reinforcement provided and $A_{s,\ required}$ = Area of reinforcement required by analysis

Figure 5.2.2.4
Reinforcement Data

TENSION LAP SPLICES FOR STAINLESS STEEL BARS WITH ≤ 12″ CONCRETE CAST BELOW

f_y=75 ksi f_c'=4 ksi

Conc. Cover	Bar Size	Reinforcement Bar Spacing															
		4″		5″		5 1/2″		6″		6 1/2″		7″		7 1/2″		≥ 8″	
		Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B	Class A	Class B
1″	3	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"
	4	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"
	5	2'-3"	2'-11"	2'-3"	2'-11"	2'-3"	2'-11"	2'-3"	2'-11"	2'-3"	2'-11"	2'-3"	2'-11"	2'-3"	2'-11"	2'-3"	2'-11"
	6	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"	3'-1"	4'-0"
	7	4'-0"	5'-3"	4'-0"	5'-3"	4'-0"	5'-3"	4'-0"	5'-3"	4'-0"	5'-3"	4'-0"	5'-3"	4'-0"	5'-3"	4'-0"	5'-3"
	8	5'-0"	6'-6"	5'-0"	6'-6"	5'-0"	6'-6"	5'-0"	6'-6"	5'-0"	6'-6"	5'-0"	6'-6"	5'-0"	6'-6"	5'-0"	6'-6"
	9	6'-2"	8'-0"	6'-2"	8'-0"	6'-2"	8'-0"	6'-2"	8'-0"	6'-2"	8'-0"	6'-2"	8'-0"	6'-2"	8'-0"	6'-2"	8'-0"
	10	7'-5"	9'-8"	7'-5"	9'-8"	7'-5"	9'-8"	7'-5"	9'-8"	7'-5"	9'-8"	7'-5"	9'-8"	7'-5"	9'-8"	7'-5"	9'-8"
	11	8'-9"	11'-5"	8'-9"	11'-5"	8'-9"	11'-5"	8'-9"	11'-5"	8'-9"	11'-5"	8'-9"	11'-5"	8'-9"	11'-5"	8'-9"	11'-5"
	14	N/A	N/A	11'-8"	15'-2"	11'-8"	15'-2"	11'-8"	15'-2"	11'-8"	15'-2"	11'-8"	15'-2"	11'-8"	15'-2"	11'-8"	15'-2"
$1\frac{1}{2}$"	3	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"
	4	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"
	5	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"
	6	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"
	7	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"
	8	3'-9"	4'-11"	3'-9"	4'-11"	3'-9"	4'-11"	3'-9"	4'-11"	3'-9"	4'-11"	3'-9"	4'-11"	3'-9"	4'-11"	3'-9"	4'-11"
	9	4'-10"	6'-3"	4'-8"	6'-1"	4'-8"	6'-1"	4'-8"	6'-1"	4'-8"	6'-1"	4'-8"	6'-1"	4'-8"	6'-1"	4'-8"	6'-1"
	10	6'-1"	7'-11"	5'-8"	7'-5"	5'-8"	7'-5"	5'-8"	7'-5"	5'-8"	7'-5"	5'-8"	7'-5"	5'-8"	7'-5"	5'-8"	7'-5"
	11	7'-6"	9'-9"	6'-10"	8'-10"	6'-10"	8'-10"	6'-10"	8'-10"	6'-10"	8'-10"	6'-10"	8'-10"	6'-10"	8'-10"	6'-10"	8'-10"
	14	N/A	N/A	9'-2"	11'-11"	9'-2"	11'-11"	9'-2"	11'-11"	9'-2"	11'-11"	9'-2"	11'-11"	9'-2"	11'-11"	9'-2"	11'-11"
2″	3	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"
	4	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"
	5	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"
	6	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"
	7	2'-11"	3'-9"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"
	8	3'-9"	4'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"
	9	4'-10"	6'-3"	3'-10"	5'-0"	3'-9"	4'-11"	3'-9"	4'-11"	3'-9"	4'-11"	3'-9"	4'-11"	3'-9"	4'-11"	3'-9"	4'-11"
	10	6'-1"	7'-11"	4'-11"	6'-4"	4'-8"	6'-0"	4'-8"	6'-0"	4'-8"	6'-0"	4'-8"	6'-0"	4'-8"	6'-0"	4'-8"	6'-0"
	11	7'-6"	9'-9"	6'-0"	7'-10"	5'-7"	7'-2"	5'-7"	7'-2"	5'-7"	7'-2"	5'-7"	7'-2"	5'-7"	7'-2"	5'-7"	7'-2"
	14	N/A	N/A	8'-8"	11'-3"	7'-10"	10'-2"	7'-7"	9'-10"	7'-7"	9'-10"	7'-7"	9'-10"	7'-7"	9'-10"	7'-7"	9'-10"
$2\frac{3}{8}$"	3	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"
	4	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"
	5	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"
	6	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"
	7	2'-11"	3'-9"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"
	8	3'-9"	4'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"
	9	4'-10"	6'-3"	3'-10"	5'-0"	3'-6"	4'-7"	3'-5"	4'-5"	3'-5"	4'-5"	3'-5"	4'-5"	3'-5"	4'-5"	3'-5"	4'-5"
	10	6'-1"	7'-11"	4'-11"	6'-4"	4'-5"	5'-9"	4'-1"	5'-3"	4'-1"	5'-3"	4'-1"	5'-3"	4'-1"	5'-3"	4'-1"	5'-3"
	11	7'-6"	9'-9"	6'-0"	7'-10"	5'-6"	7'-1"	5'-0"	6'-6"	4'-11"	6'-4"	4'-11"	6'-4"	4'-11"	6'-4"	4'-11"	6'-4"
	14	N/A	N/A	8'-8"	11'-3"	7'-10"	10'-2"	7'-2"	9'-4"	6'-9"	8'-9"	6'-9"	8'-9"	6'-9"	8'-9"	6'-9"	8'-9"
≥ 3″	3	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"	1'-2"	1'-6"
	4	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"	1'-6"	2'-0"
	5	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"	1'-11"	2'-6"
	6	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"	2'-3"	3'-0"
	7	2'-11"	3'-9"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"	2'-8"	3'-5"
	8	3'-9"	4'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"	3'-0"	3'-11"
	9	4'-10"	6'-3"	3'-10"	5'-0"	3'-6"	4'-7"	3'-5"	4'-5"	3'-5"	4'-5"	3'-5"	4'-5"	3'-5"	4'-5"	3'-5"	4'-5"
	10	6'-1"	7'-11"	4'-11"	6'-4"	4'-5"	5'-9"	4'-1"	5'-3"	3'-10"	5'-0"	3'-10"	5'-0"	3'-10"	5'-0"	3'-10"	5'-0"
	11	7'-6"	9'-9"	6'-0"	7'-10"	5'-6"	7'-1"	5'-0"	6'-6"	4'-8"	6'-0"	4'-4"	5'-7"	4'-3"	5'-6"	4'-3"	5'-6"
	14	N/A	N/A	8'-8"	11'-3"	7'-10"	10'-2"	7'-2"	9'-4"	6'-8"	8'-8"	6'-2"	8'-0"	5'-9"	7'-6"	5'-8"	7'-4"

Table includes modification factors for reinforcement location, epoxy coating, normal weight concrete and reinforcement confinement as specified in AASHTO Articles 5.11.2.1.2 and 5.11.2.1.3. Reinforcement confinement is conservatively calculated by taking transverse reinforcement index as 0. Excess reinforcement factor is taken conservatively as 1.0. Tension lap splice lengths are based on AASHTO Article 5.11.5.3.1. Concrete cover is defined as the cover to the bar being considered. For concrete cover or bar spacing that falls between table values, conservatively use lap splice shown in the table for smaller concrete cover or bar spacing.

TENSION LAP SPLICES	Percent of A_s spliced within required lap length	
$A_{s,\ provided}/A_{s,\ required}$	≤ 50	> 50
≥ 2	Class A	Class B
< 2	Class B	Class B

Where: $A_{s,\ provided}$ = Area of reinforcement provided and $A_{s,\ required}$ = Area of reinforcement required by analysis

Figure 5.2.2.5
Reinforcement Data

DEVELOPMENT LENGTH FOR STANDARD HOOKS IN TENSION

For plain and epoxy bars, f_y = 60 ksi f_c'= 4ksi

For stainless steel bars, f_y = 75 ksi

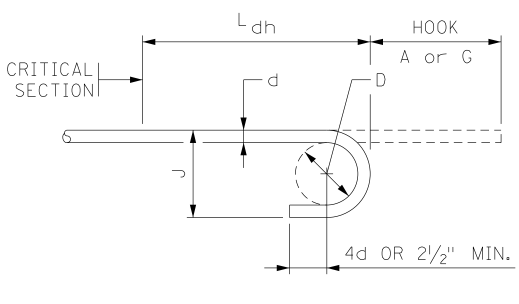
Hooked Bar Development Length, L_{dh}
When: Side Cover ≥ 2.5" AND
For 90° Hooks, Concrete Cover ≥ 2"
in the direction of bar extension

Bar Size	Plain Uncoated Bars	Epoxy Coated Bars	Stainless Steel Bars
3	6"	7"	8″
4	8"	10"	10″
5	10"	1'-0"	1′-0″
6	1'-0"	1'-2"	1'-3"
7	1'-2"	1'-4"	1'-5"
8	1'-4"	1'-7"	1'-7"
9	1'-6"	1'-9"	1'-10"
10	1'-8"	2'-0"	2'-1"
11	1'-10"	2'-2"	2'-3"
14	2'-9"	3'-3"	3'-5"

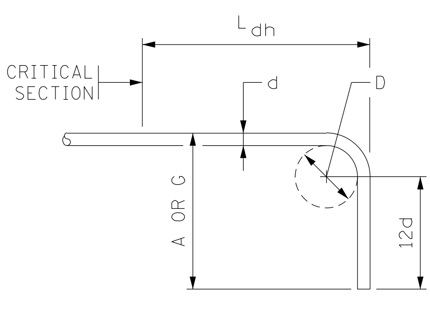
Hooked Bar Development Length, L_{dh}
When: Side Cover < 2.5" OR
For 90° Hooks, Concrete Cover < 2"
in the direction of bar extension

Bar Size	Plain Uncoated Bars	Epoxy Coated Bars	Stainless Steel Bars
3	8"	9"	9"
4	10"	1'-0"	1'-0"
5	1'-0"	1'-3"	1'-3"
6	1'-3"	1'-6"	1'-6"
7	1'-5"	1'-8"	1'-9"
8	1'-7"	1'-11"	2'-0"
9	1'-10"	2'-2"	2'-3"
10	2'-1"	2'-5"	2'-7"
11	2'-3"	2'-9"	2'-10"
14	2'-9"	3'-3"	3'-5"

Tables include modification factors per LRFD Art. 5.11.2.4.2 for normal weight concrete, bar coating, and reinforcement confinement. The reinforcement confinement factor is not applicable to bars larger than No. 11 bars. Note that MnDOT allows use of No. 14 bar standard hooks for concrete strengths up to 10 ksi.



180° BEND

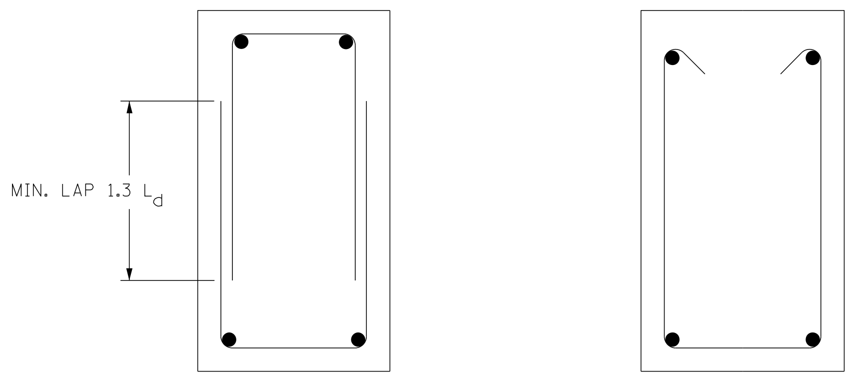


90° BEND

STANDARD HOOK DIMENSIONS

BAR SIZE	D	180° HOOKS		90° HOOKS
		A OR G	J	A OR G
3	2 1/4"	5"	3"	6"
4	3"	6"	4"	8"
5	3 3/4"	7"	5"	10"
6	4 1/2"	8"	6"	1'-0"
7	5 1/4"	10"	7"	1'-2"
8	6"	11"	8"	1'-4"
9	9 1/2"	1'-3"	11 3/4"	1'-7"
10	10 3/4"	1'-5"	1'-1 1/4"	1'-10"
11	12"	1'-7"	1'-2 3/4"	2'-0"
14	18 1/4"	2'-3"	1'-9 3/4"	2'-7"

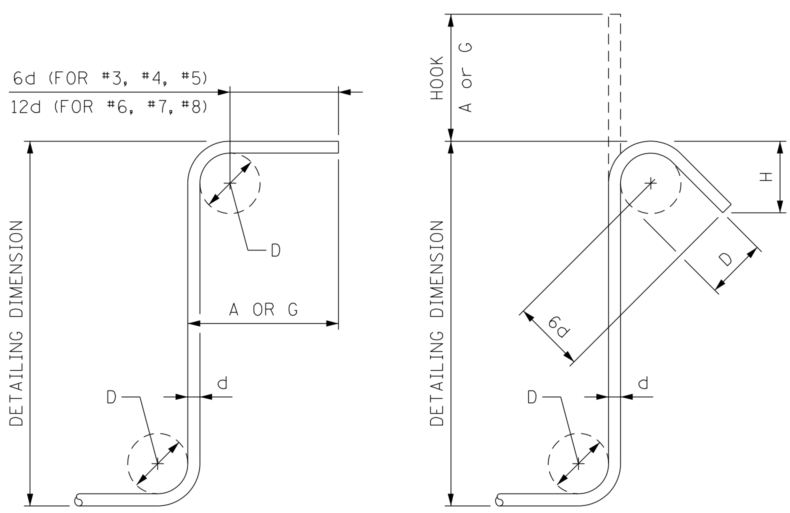
Figure 5.2.2.6
Reinforcement Data



L_d = DEVELOPMENT LENGTH

METHODS FOR ANCHORAGE OF SHEAR REINFORCEMENT

SEE AASHTO LRFD 5.11.2.6.2 AND 5.11.2.6.4



90° BEND 135° BEND

STIRRUP AND TIE HOOK DIMENSIONS				
BAR SIZE	D	90° HOOKS	135° HOOKS	
		A OR G	A OR G	H *
3	1 1/2"	4"	4"	2 1/2"
4	2"	4 1/2"	4 1/2"	3"
5	2 1/2"	6"	5 1/2"	3 3/4"
6	4 1/2"	1'-0"	8"	4 1/2"
7	5 1/4"	1'-2"	9"	5 1/4"
8	6"	1'-4"	10 1/2"	6"

MINIMUM HORIZONTAL BAR SPACING (℄ TO ℄)		
BAR SIZE	CONCRETE MIX: 1G52 AND 3B52	CONCRETE MIX: 3JM, 3YHPC-M, 3YHPC-S, 3YLCHPC-M, 3YLCHPC-S, 3Y42, 3S52, 3Y82 AND 3W82
3	2 5/8"	1 7/8"
4	2 3/4"	2"
5	2 7/8"	2 1/8"
6	3"	2 1/4"
7	3 1/8"	2 3/8"
8	3 1/4"	2 1/2"
9	3 1/2"	2 7/8"
10	3 5/8"	3 1/4"
11	3 3/4"	3 5/8"
14	4 1/4"	4 1/4"

SEE AASHTO LRFD 5.10.3.1

NOTE: MINIMUM HORIZONTAL BAR SPACING SHALL ALSO APPLY TO THE DISTANCE FROM A CONTACT LAP SPLICE TO ADJACENT SPLICES OR BARS.

Figure 5.2.2.7
Reinforcement Data

5.2.3 General Reinforcement Practices

Reinforcement practices follow those shown by the Concrete Reinforcing Steel Institute (C.R.S.I.) in the *Manual of Standard Practice*. These practices include:

1) For bent bars, omit the last length dimension on reinforcement bar details.
2) Use standard length bars for all but the last bar in long bar runs.
3) Use a maximum length of 60 feet for #4 deck or slab bars and 40 feet for other applications.
4) Use a maximum length of 60 feet for bars #5 and larger.
5) Recognize that bar cutting and bending tolerances are ±1 inch for bars and that this tolerance is important for long straight bars that do not have lap splices to provide dimensional flexibility. Refer to MnDOT document *Suggested Reinforcement Detailing Practices*, which is located at http://www.dot.state.mn.us/bridge/standards.html, for more guidance on rebar detailing to account for tolerances.
6) Reinforcement bars longer than 60 feet or larger than #11 are available only on special order, and should be avoided. Designers should check with the State Bridge Design Engineer before using special order sizes or lengths.

5.2.4 Reinforcement Bar Couplers

Reinforcement bar couplers are expensive compared to conventional lap splices. Where lap splices cannot be readily used (bridge widening projects, staged construction, large river pier longitudinal bars—anywhere that the available space for a rebar projection is limited), couplers should be considered. Where possible, stagger reinforcement bar couplers in order to distribute the stiffness of the couplers. There are numerous coupler types and sizes. For members that require couplers, consider the coupler outside diameter and length when detailing reinforcement, in order to avoid congestion and clear cover issues.

5.2.5 Adhesive Anchors

Similar to bar couplers, adhesive anchors are expensive. Adhesive anchors are typically used to attach secondary structural members to new concrete or primary structural members to existing (old) concrete. A typical use is to attach a metal rail to a concrete base.

See Article 13.3.2 of this manual for an adhesive anchor design example.

Adhesive anchors shall not be used for constant tension applications.

APPENDIX 5-A

MnDOT BRIDGE OFFICE REBAR LAP SPLICE GUIDE

> Based on LRFD 5.11.2 and 5.11.5
> Use of epoxy coated bars is assumed
> Excess reinforcement factor λ_{er} is taken equal to 1.0

DECKS:

Top Transverse Deck Bars

See LRFD Bridge Design Manual Table 9.2.1.1 or Table 9.2.1.2 for bar size and spacing. A Class A splice is provided where all top transverse bar splices occur between beams, with 50% of the bars spliced at a given location. A Class B splice is provided where 100% of the bars are spliced at a given location between beams or where 50% of the bars are spliced at a given location over beams. Avoid splicing 100% of bars over beams.

Top Transverse Deck Bar Lap Splice Lengths				
Concrete Cover to Bar Being Considered	Bar Spacing	Bar Size	All Splices Between Beams and 50% are at Same Location *(preferred)*	100% of Splices at Same Location Between Beams or 50% of Splices Over Beams at Same Location
3"	> 5"	#4	1'-6"	1'-11"
		#5	1'-10"	2'-5"
		#6	2'-2"	2'-10"
	5"	#4	1'-6"	1'-11"
		#5	1'-10"	2'-5"
		#6	2'-9"	3'-7"

Top Longitudinal Deck Bars

See LRFD Bridge Design Manual Table 9.2.1.1 & Figure 9.2.1.6 or Table 9.2.1.2 & Figure 9.2.1.7 for bar size and spacing. Detail reinforcement such that no more than 50% of top longitudinal bars are spliced at any cross-section through the deck (Class A splice).

Top Longitudinal Deck Bar Lap Splice Lengths		
Concrete Cover to Bar Being Considered	Bar Size	Lap Splice Length
≥ 3 1/2"	#4	1'-6"
	#5	1'-10"
	#6	2'-2"

APPENDIX 5-A (CONTINUED)

MnDOT BRIDGE OFFICE REBAR LAP SPLICE GUIDE

> Based on LRFD 5.11.2 and 5.11.5
> Use of epoxy coated bars is assumed
> Excess reinforcement factor λ_{er} is taken equal to 1.0

DECKS: (cont'd)

Bottom Transverse Deck Bars

See LRFD Bridge Design Manual Table 9.2.1.1 or Table 9.2.1.2 for bar size and spacing. A Class A splice is provided where all bottom transverse bars are spliced over beams, with 50% of the bars spliced at a given location. A Class B splice is provided where 100% of the bars are spliced at a given location over beams or where 50% of the bars are spliced at a given location between beams. Avoid splicing 100% of bars between beams.

Bottom Transverse Deck Bar Lap Splice Lengths				
Concrete Cover to Bar Being Considered	Bar Spacing	Bar Size	All Splices Over Beams and 50% are at Same Location *(preferred)*	100% of Splices at Same Location Over Beams or 50% of Splices Between Beams at Same Location
1"	≥ 4"	#4	1'-10"	2'-5"
		#5	2'-9"	3'-6"
		#6	3'-9"	4'-10"

Bottom Longitudinal Deck Bars

See LRFD Bridge Design Manual Table 9.2.1.1 or Table 9.2.1.2 & Figure 9.2.1.7 for bar size and spacing. A Class B splice is provided. Where possible, detail such that no more than 50% of the bottom longitudinal deck bars are spliced at a given cross-section through the deck.

Bottom Longitudinal Deck Bar Lap Splice Lengths			
Concrete Cover to Bar Being Considered	Bar Spacing	Bar Size	50% of Splices at Same Location *(Preferred)* or 100% of Splices at Same Location
≥ 1 1/2"	≥ 4"	#4	1'-11"
		#5	3'-0"
		#6	3'-7"

APPENDIX 5-A (CONTINUED)

MnDOT BRIDGE OFFICE REBAR LAP SPLICE GUIDE

> Based on LRFD 5.11.2 and 5.11.5
> Use of epoxy coated bars is assumed
> Excess reinforcement factor λ_{er} is taken equal to 1.0

ABUTMENTS:

Abutment and Wingwall Vertical Bars

Back face vertical bars are all spliced at the same location, so a Class B splice is used. See LRFD 5.11.3.1. Front face bars are conservatively assumed to act as tension reinforcement, so compressive development lengths are not used in splice length computations. Although all front face bars are spliced at the same location, excess reinforcement is provided, so a Class A splice is used.

Abutment and Wingwall Vertical Bar Lap Splice Lengths

Concrete Cover to Bar Being Considered	Bar Size	Back Face Bar Spacing			Front Face Bar Spacing
		4"	5"	≥6"	≥6"
≥ 2"	#4	--	--	--	1'-6"
	#5	3'-0"	2'-5"	2'-5"	1'-10"
	#6	3'-7"	3'-7"	3'-7"	2'-9"
	#7	4'-6"	4'-2"	4'-2"	3'-2"
	#8	5'-11"	4'-9"	4'-9"	3'-8"
	#9	7'-6"	6'-0"	5'-10"	--
	#10	9'-6"	7'-7"	7'-2"	--
	#11	11'-8"	9'-4"	8'-8"	--
	#14	--	13'-5"	11'-10"	--

APPENDIX 5-A (CONTINUED)

MnDOT BRIDGE OFFICE REBAR LAP SPLICE GUIDE

> Based on LRFD 5.11.2 and 5.11.5
> Use of epoxy coated bars is assumed
> Excess reinforcement factor λ_{er} is taken equal to 1.0

ABUTMENTS: (cont'd)

Abutment and Wingwall Horizontal Bars

All horizontal bars are assumed to have more than 12" of concrete cast below. For abutments, horizontal bars are assumed to provide excess reinforcement, so a Class A splice is used. For long wingwalls on separate footings, horizontal bars become primary reinforcement, so a Class B splice is used.

Abutment and Wingwall Horizontal Bar Lap Splice Lengths				
Concrete Cover to Bar Being Considered	Bar Size	Abutment Horizontal Bar Spacing	Wingwall Horizontal Bar Spacing	
		≥ 6"	4"	≥ 5"
≥ 2"	#4	1'-11"	2'-6"	2'-6"
	#5	2'-5"	3'-4"	3'-1"
	#6	3'-1"	4'-0"	4'-0"
	#7	3'-7"	5'-1"	4'-8"
	#8	4'-1"	6'-8"	5'-4"

APPENDIX 5-A (CONTINUED)

MnDOT BRIDGE OFFICE REBAR LAP SPLICE GUIDE

> Based on LRFD 5.11.2 and 5.11.5
> Use of epoxy coated bars is assumed
> Excess reinforcement factor λ_{er} is taken equal to 1.0

PIERS:

Pier Cap Top Longitudinal Bars

All horizontal bars are assumed to have more than 12″ of concrete cast below. For splices between columns where no more than 50% of the bars are spliced at the same location, a Class A splice is used. For all other cases, use a Class B splice.

Pier Cap Top Longitudinal Bar Lap Splice Lengths						
Concrete Cover to Bar Being Considered	Bar Size	All Splices Located Between Columns and ≤ 50% of Bars Are Spliced at Same Location				
		Bar Spacing				
		4"	5"	5 1/2"	6"	≥ 6 1/2"
≥ 2 1/2"	#5	2'-7"	2'-5"	2'-5"	2'-5"	2'-5"
	#6	3'-1"	3'-1"	2'-10"	2'-10"	2'-10"
	#7	3'-11"	3'-7"	3'-7"	3'-7"	3'-7"
	#8	5'-2"	4'-1"	4'-1"	4'-1"	4'-1"
	#9	6'-6"	5'-3"	4'-9"	4'-8"	4'-8"
	#10	8'-3"	6'-7"	6'-0"	5'-6"	5'-6"
	#11	10'-2"	8'-2"	7'-5"	6'-10"	6'-8"
	#14	--	11'-9"	10'-8"	9'-9"	9'-1"
	Bar Size	All Splices Located Between Columns and > 50% of Bars Are Spliced at Same Location				
		Bar Spacing				
		4"	5"	5 1/2"	6"	≥ 6 1/2"
	#5	3'-4"	3'-1"	3'-1"	3'-1"	3'-1"
	#6	4'-0"	4'-0"	3'-8"	3'-8"	3'-8"
	#7	5'-1"	4'-8"	4'-8"	4'-8"	4'-8"
	#8	6'-8"	5'-4"	5'-4"	5'-4"	5'-4"
	#9	8'-6"	6'-9"	6'-2"	6'-0"	6'-0"
	#10	10'-9"	8'-7"	7'-10"	7'-2"	7'-2"
	#11	13'-3"	10'-7"	9'-8"	8'-10"	8'-7"
	#14	--	15'-3"	13'-10"	12'-9"	11'-10"

APPENDIX 5-A (CONTINUED)

MnDOT BRIDGE OFFICE REBAR LAP SPLICE GUIDE

> Based on LRFD 5.11.2 and 5.11.5
> Use of epoxy coated bars is assumed
> Excess reinforcement factor λ_{er} is taken equal to 1.0

PIERS: (cont'd)

Pier Cap Bottom Longitudinal Bars

For splices over columns where no more than 50% of the bars are spliced at the same location, a Class A splice is used. For all other cases, use a Class B splice.

Pier Cap Bottom Longitudinal Bar Lap Splice Lengths						
Concrete Cover to Bar Being Considered	Bar Size	All Splices Located Over Columns and ≤ 50% of Bars Are Spliced at Same Location				
		Bar Spacing				
		4"	5"	5 1/2"	6"	≥ 6 1/2"
≥ 2 1/2"	#5	2'-3"	1'-10"	1'-10"	1'-10"	1'-10"
	#6	2'-9"	2'-9"	2'-2"	2'-2"	2'-2"
	#7	3'-6"	3'-2"	3'-2"	3'-2"	3'-2"
	#8	4'-6"	3'-8"	3'-8"	3'-8"	3'-8"
	#9	5'-9"	4'-7"	4'-2"	4'-1"	4'-1"
	#10	7'-4"	5'-10"	5'-4"	4'-11"	4'-10"
	#11	9'-0"	7'-2"	6'-7"	6'-0"	5'-10"
	#14	--	10'-4"	9'-5"	8'-8"	8'-1"
	Bar Size	All Splices Located Over Columns and > 50% of Bars Are Spliced at Same Location				
		Bar Spacing				
		4"	5"	5 1/2"	6"	≥ 6 1/2"
	#5	3'-0"	2'-5"	2'-5"	2'-5"	2'-5"
	#6	3'-7"	3'-7"	2'-10"	2'-10"	2'-10"
	#7	4'-6"	4'-2"	4'-2"	4'-2"	4'-2"
	#8	5'-11"	4'-9"	4'-9"	4'-9"	4'-9"
	#9	7'-6"	6'-0"	5'-5"	5'-4"	5'-4"
	#10	9'-6"	7'-7"	6'-11"	6'-4"	6'-4"
	#11	11'-8"	9'-4"	8'-6"	7'-10"	7'-7"
	#14	--	13'-5"	12'-3"	11'-3"	10'-5"

APPENDIX 5-A (CONTINUED)

MnDOT BRIDGE OFFICE REBAR LAP SPLICE GUIDE

> Based on LRFD 5.11.2 and 5.11.5
> Use of epoxy coated bars is assumed
> Excess reinforcement factor λ_{er} is taken equal to 1.0

PIERS: (cont'd)

Other Pier Cap Longitudinal Bars Located on Side Faces of Pier Cap

Longitudinal bars located on the side faces of pier caps (typically skin or shrinkage and temperature reinforcement) are assumed to have more than 12" of concrete cast below. For these bars, a Class B splice is used.

Lap Splice Lengths for Longitudinal Bars Located on Side Faces of Pier Cap		
Concrete Cover to Bar Being Considered	Bar Size	Bar Spacing ≥ 4"
≥ 2 1/2"	#4	2'-6"
	#5	3'-4"
	#6	4'-0"
	#7	5'-1"

Pier Column Vertical Bars

For pier columns, all splices occur at the same location, so a Class B splice is used.

Pier Column Vertical Bar Lap Splice Lengths						
Concrete Cover to Bar Being Considered	Bar Size	Bar Spacing				
		4"	5"	5 1/2"	6"	≥ 6 1/2"
≥ 2 3/8"	#6	3'-7"	3'-7"	2'-10"	2'-10"	2'-10"
	#7	4'-6"	4'-2"	4'-2"	4'-2"	4'-2"
	#8	5'-11"	4'-9"	4'-9"	4'-9"	4'-9"
	#9	7'-6"	6'-0"	5'-5"	5'-4"	5'-4"
	#10	9'-6"	7'-7"	6'-11"	6'-4"	6'-4"
	#11	11'-8"	9'-4"	8'-6"	7'-10"	7'-7"
	#14	--	13'-5"	12'-3"	11'-3"	10'-5"

APPENDIX 5-A (CONTINUED)

MnDOT BRIDGE OFFICE REBAR LAP SPLICE GUIDE

> Based on LRFD 5.11.2 and 5.11.5
> Use of epoxy coated bars is assumed
> Excess reinforcement factor λ_{er} is taken equal to 1.0

SLAB SPANS:

Top Bars

This table applies to both top longitudinal and transverse bars. All bars are assumed to have more than 12" of concrete cast below. A Class B splice is used.

Top Longitudinal and Transverse Bar Lap Splice Lengths						
Concrete Cover to Bar Being Considered	Bar Size	Bar Spacing				
		4"	5"	6"	7"	≥ 8"
≥ 3"	#4	2'-6"	2'-6"	2'-6"	2'-6"	2'-6"
	#5	3'-4"	3'-1"	3'-1"	3'-1"	3'-1"
	#6	4'-0"	4'-0"	3'-8"	3'-8"	3'-8"
	#7	5'-1"	4'-8"	4'-8"	4'-4"	4'-4"
	#8	6'-8"	5'-4"	5'-4"	4'-11"	4'-11"
	#9	8'-6"	6'-9"	6'-0"	6'-0"	6'-0"
	#10	10'-9"	8'-7"	7'-2"	6'-9"	6'-9"
	#11	13'-3"	10'-7"	8'-10"	7'-7"	7'-6"
	#14	--	15'-3"	12'-9"	10'-11"	9'-11"

APPENDIX 5-A (CONTINUED)

MnDOT BRIDGE OFFICE REBAR LAP SPLICE GUIDE

> Based on LRFD 5.11.2 and 5.11.5
> Use of epoxy coated bars is assumed
> Excess reinforcement factor λ_{er} is taken equal to 1.0

SLAB SPANS: (cont'd)

Bottom Bars

The table applies to both bottom longitudinal and transverse bars. A Class B splice is used.

Bottom Longitudinal and Transverse Bar Lap Splice Lengths			
Concrete Cover to Bar Being Considered	Bar Size	Bar Spacing	
		4"	≥ 5"
≥ 1 1/2"	#4	1'-11"	1'-11"
	#5	3'-0"	3'-0"
	#6	3'-7"	3'-7"
	#7	4'-8"	4'-8"
	#8	5'-11"	5'-11"
	#9	7'-6"	7'-3"
	#10	9'-6"	8'-11"
	#11	11'-8"	10'-7"
	#14	--	14'-4"

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Rating Factors

A. Calculate Inventory Rating Factor for Flexure

$$RF_{Inv} = \frac{175.95 - (1.25)(0.92) - (1.50)(3.23)}{(1.75)(69.12)}$$

$RF_{Inv} = 1.41$

B. Calculate Operating Rating Factor for Flexure

$$RF_{Oper} = \frac{175.95 - (1.25)(0.92) - (1.50)(3.23)}{(1.35)(69.12)}$$

$RF_{Oper} = 1.82$

Shear Force effect

[Eqn. 6A.4.2.1-2]

A. Capacity for Shear Strength Limit State

$C = \varphi_c \varphi_s \phi R_n$

[6A.4.2.3]

For a new bridge $\varphi_c = 1.00$

[6A.4.2.4]

For all timber bridges $\varphi_s = 1.00$

For shear, $\phi R_n = \phi_v V_n = \phi_v \cdot F_v \cdot b \cdot d_{lam} /1.5$

From Article 8.7.4 for this transverse glued laminated deck in shear:

$\phi_v = 0.75$

$F_v = 0.606$ ksi for Southern Pine (ID No. 48)

$b = 12.0$ in

$d_{lam} = 5.0$ in

$\phi_v V_n = 0.75 \cdot 0.606 \cdot 12.0 \cdot 5.0 /1.5 = 18.18$ kips

Therefore, $C = 1.00 \cdot 1.00 \cdot 18.18 = 18.18$ kips

B. Load Factors

The load factors as found in the MBE for the general load rating equation at the Inventory Rating level are:

[Table 6A.4.2.2-1]

$\gamma_{DC} = 1.25$

$\gamma_{DW} = 1.50$

$\gamma_P = 1.0$ (there are no other permanent loads and so this will be neglected in the final calculation)

$\gamma_{LL} = 1.75$

The only change to the Operating Rating level is for the live load factor:
γ_{LL} = 1.35

C. Force Effects for Shear

The force effects for shear were calculated in Article 8.7.4 on a per ft basis. The values shown here are taken at a distance "d_{lam}" away from the support (the FWC is not included in V_{dw}):

V_{dc} = 0.051 kips
V_{dw} = 0.190 kips
V_{truck} = 3.555 kips (truck governs over tandem)

Rating Factors

A. Calculate Inventory Rating Factor for Shear

$$RF_{Inv} = \frac{18.18 - (1.25)(0.051) - (1.50)(0.190)}{(1.75)(3.555)}$$

RF_{Inv} = 2.87

B. Calculate Operating Rating Factor for Shear

$$RF_{Oper} = \frac{18.18 - (1.25)(0.051) - (1.50)(0.190)}{(1.35)(3.555)}$$

RF_{Oper} = 3.72

the Bridge Architectural Specialist. In those cases, acceptable construction joint locations are to be shown on the preliminary plan.

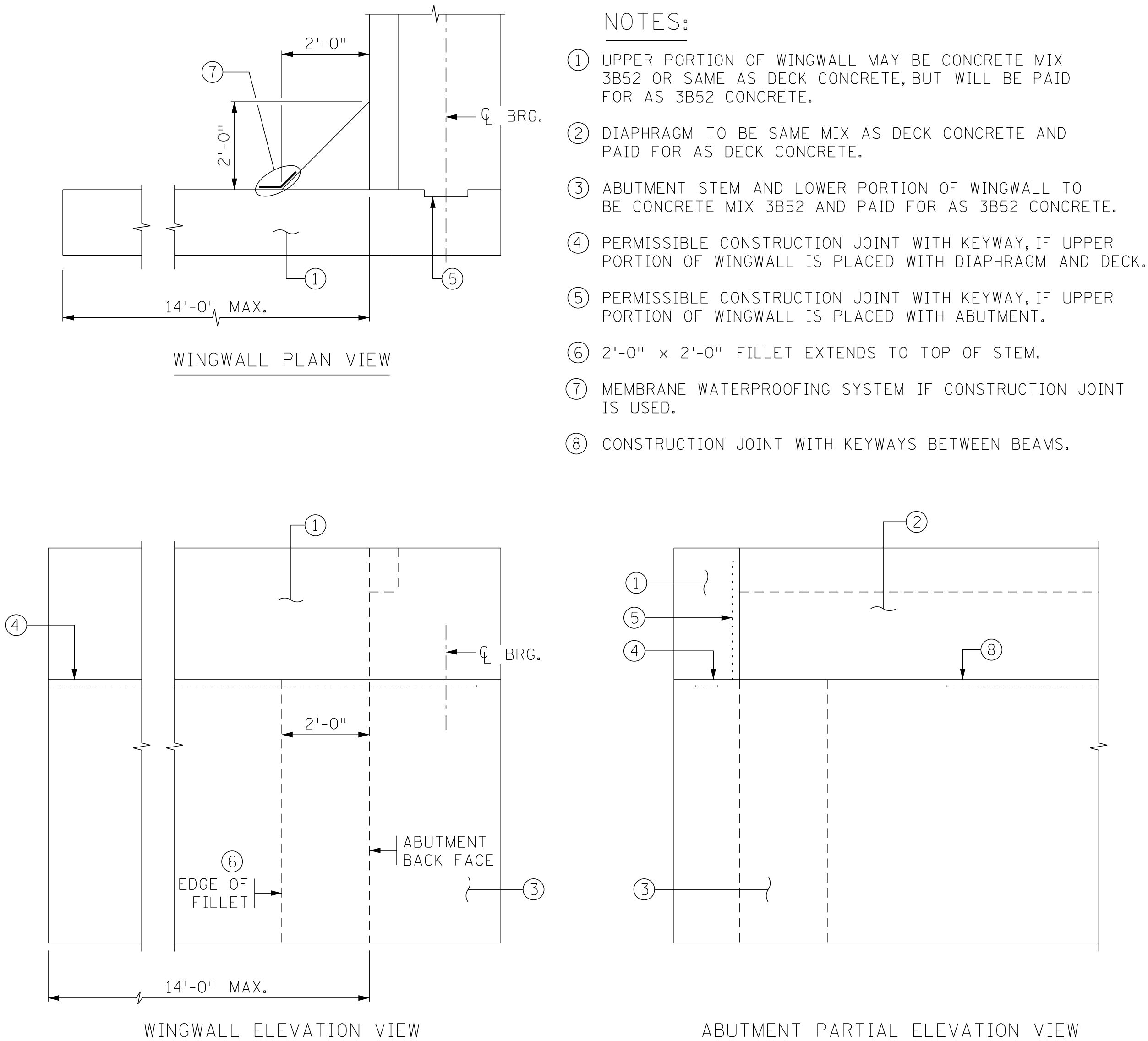

Figure 11.1.1.1a
Permissible Construction Joints For Integral Abutments With Wingwalls Parallel to Roadway

NOTES:

1. CONSTRUCTION JOINT AT TOP OF ABUTMENT STEM WITH KEYWAYS BETWEEN BEAMS.
2. PERMISSIBLE CONSTRUCTION JOINT WITH KEYWAY, IF UPPER PORTION OF WINGWALL IS PLACED WITH DIAPHRAGM AND DECK.
3. PERMISSIBLE CONSTRUCTION JOINT WITH KEYWAY (ABOVE ABUTMENT STEM), IF UPPER PORTION OF WINGWALL IS PLACED WITH ABUTMENT.
4. MEMBRANE WATERPROOFING SYSTEM IF CONSTRUCTION JOINT IS USED.

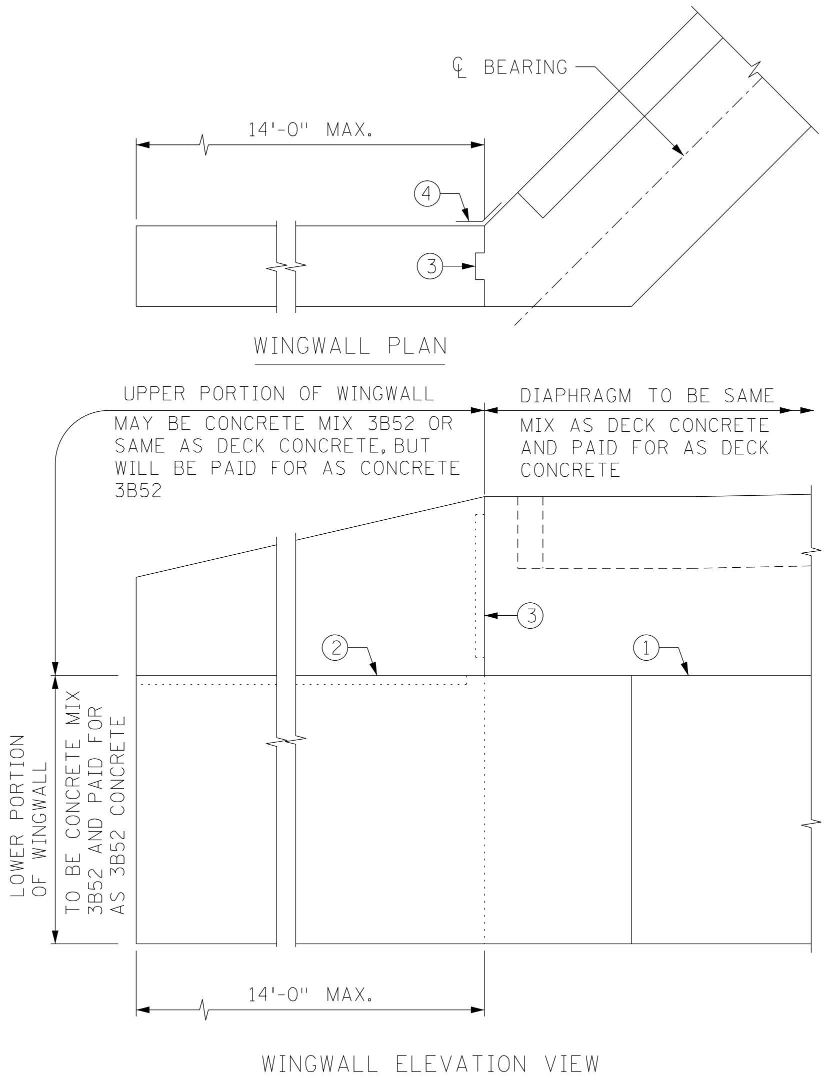

Figure 11.1.1.1b
Permissible Construction Joints For Integral Abutments With Flared Wingwalls

For abutment stem shear reinforcement, use #6 bars spaced at a maximum of 12 inches between piles along the length of the abutment. These bars are designated A601E and A605E in Figures 11.1.1.2 and 11.1.1.3.

For abutment stem back face vertical dowels, select bar size, spacing and length from Table 11.1.1.1. Embed dowels 4'-6" into the stem. These bars are designated A_04E in Figures 11.1.1.2 and 11.1.1.3. Where table shows a maximum spacing of 12", space A_04E dowels with the abutment stem shear reinforcement (A601E) between piles. Where table shows a maximum spacing of 6", space every other A_04E dowel with the abutment stem shear reinforcement (A601E) between piles.

Table 11.1.1.1 Abutment Stem Vertical Dowels (A_04E) Minimum Required Bar Size and Length

Beam Size (in)	Bar Size & Max Spacing	Bar Projection into Abutment Diaphragm
14	#5 @ 12"	8"
18	#6 @ 12"	1'-0"
22	#6 @ 12"	1'-4"
27	#6 @ 12"	1'-9"
36	#7 @ 12"	2'-6"
45	#7 @ 12"	3'-3"
54	#6 @ 6"	4'-0"
63	#6 @ 6"	4'-9"
72	#6 @ 6"	5'-6"

For abutment stem front face vertical dowels, use #5 bars spaced at a maximum of 12 inches between beams. These bars are designated A506E in Figures 11.1.1.2 through 11.1.1.4. Do not space with the other abutment stem reinforcement, but instead space with the abutment diaphragm transverse bars (S501E).

For abutment stem front and back face horizontal reinforcement, use #6 bars spaced at a maximum of 9 inches. These bars are designated A602E in Figures 11.1.1.2 and 11.1.1.3. Account for changes in abutment seat height by varying bar spacing or the number of bars.

For the abutment stem top and bottom longitudinal bars, use 4-#6 bars on the top and bottom faces of the stem for piles spaced at 9 feet or less. These bars are designated A602E in Figures 11.1.1.2 and 11.1.1.3. When pile spacing exceeds 9 feet, use #6 bars in the corners with two additional

#7 bars on the top and bottom faces of the stem. These bars are designated A602E and A707E in Figures 11.1.1.2 and 11.1.1.3.

Include 2-#4 pile ties on each side of each pile. These bars are designated A403E in Figures 11.1.1.2 and 11.1.1.3.

For abutment diaphragm transverse reinforcement, use #5 bars, which are designated S501E in Figures 11.1.1.2 through 11.1.1.4. Space them at a maximum of 12 inches between beams, matching the abutment stem front face vertical dowels (A506E).

For abutment diaphragm deck ties, approach panel ties and fillet ties, use #6 bars spaced at a maximum of 12 inches between beams to match the abutment stem front face vertical dowels. These bars are designated S604E, S605S and S606E, respectively in Figures 11.1.1.2 through 11.1.1.4. Additionally, place S604E and S605S bars outside the fascia beams to the end of the diaphragm. Do not place S606E fillet ties outside of the fascia beams. Place two additional S604E diaphragm deck ties at equal spaces at the end of each beam.

Provide 1-#4 horizontal bar in the fillet area of the abutment diaphragm that runs the width of the fillet. This bar is designated S407E in Figures 11.1.1.2 through 11.1.1.4.

For abutment diaphragm front face and back face horizontal reinforcement, use equally spaced #6 bars. These bars are designated S602E and S603E, respectively in Figures 11.1.1.2 through 11.1.1.4. Determine the number of bars using Table 11.1.1.2.

Table 11.1.1.2
Abutment Diaphragm Horizontal Bars (S602E & S603E)
Minimum Required Number of #6 Bars, Each Face

Beam Size (in)	**Beam Spacing (feet)**				
	≤ 9	**10**	**11**	**12**	**13**
14	2	2	2	2	2
18	2	2	2	2	2
22	2	2	2	2	2
27	3	3	3	3	3
36	3	3	3	3	4
45	4	4	4	4	5
54	5	5	5	5	6
63	6	6	6	7	7
72	7	7	7	8	9