NDOT STRUCTURES MANUAL
REVISION 2019-5
March 2019

Revision Summary

Page(s)	Manual Subsection	Description
14-11	14.3.1.5	Correct LRFD references. Add requirement for columns to meet connection and shear capacity requirements from the AASHTO Guide Specifications for LRFD Seismic Bridge Design. Revise maximum spacing of lateral reinforcement in plastic hinge regions of drilled shafts.
14-12	14.3.1.7.1	Correct LRFD reference. Clarify discussion about LRFD.
14-13	14.3.1.7.3	Correct LRFD references.
14-13,14	14.3.1.8	Correct LRFD references. Correct lap splice terminology for LRFD. Revise standard minimum lap splice lengths.
14-14	14.3.1.9	Correct LRFD references.
14-23	14.5.2.1	Correct LRFD references. Revise tensile stress limit.

Revisions indicated by underscored text.

14.3.1.5 Lateral Confinement Reinforcement

14.3.1.5.1 Columns

Reference: LRFD Article 5.11.4

All lateral column reinforcement shall be detailed for Zones 3 and 4 requirements in LRFD Article 5.11.4. Lateral column reinforcement in expected plastic hinge zones shall also meet the shear capacity requirements SDC C & D in Section 8.6 of the AASHTO Guide Specifications for LRFD Seismic Bridge Design. This section of the *Guide Specifications* may also be used to calculate the shear capacity of columns outside the expected plastic hinge zone. Column connections shall meet the requirements in Section 8.13 of the AASHTO Guide Specifications for LRFD Seismic Bridge Design.

Lateral reinforcement for compression members shall consist of either spiral reinforcement, welded hoops or a combination of lateral ties and cross ties. Ties shall only be used when it is not practical to provide spiral or hoop reinforcement. Where longitudinal bars are required outside the spiral or hoop reinforcement, they shall have lateral support provided by bars spaced and hooked as required for cross ties. The hooked bars shall extend into the core of the spiral or hoop a full development length.

14.3.1.5.2 Drilled Shafts

The reinforcing steel cage for drilled shafts shall extend the full length of the pile.

The length of the plastic hinge confinement reinforcement shall be determined by appropriate analysis but shall not be less than the requirements of LRFD Article 5.11.4.5.2.

The designer should maximize the size of longitudinal and transverse reinforcement to increase the openings between all reinforcement to allow concrete to pass through the cage during placement. The maximum spacing of lateral reinforcement in plastic hinge regions shall be as required in Section 8.8.9 of the AASHTO Guide Specifications for LRFD Seismic Bridge Design in lieu of the requirements in LRFD Article 5.11.4.1.5.

14.3.1.7.1 Development Length in Tension

Reference: LRFD Article 5.10.8.2

The development of bars in tension involves calculating the basic development length, l_{db}, which is modified by factors to reflect bar spacing, cover, enclosing transverse reinforcement, top bar effect, concrete density, and the ratio of required area to provide the area of reinforcement to be developed.

The development length, l_d (including all applicable modification factors), must not be less than 12 in.

14.3.1.7.3 Standard End Hook Development Length in Tension

Reference: LRFD Article 5.10.8.2.4

Standard hooks use a 90° and 180° bend to develop bars in tension where space limitations restrict the use of straight bars. End hooks on compression bars are not effective for development length purposes.

Refer to the figure in the commentary of LRFD Article C5.10.8.2.4 for hooked-bar details for the development of standard hooks. Use the same figure for both uncoated and coated bars, modified as appropriate by the factors noted in Section 14.3.1.7.1.

14.3.1.8 Splices

Reference: LRFD Article 5.10.8.4

14.3.1.8.1 Types/Usage

The following presents NDOT practices on the types of splices and their usage:

1. Lap Splices. NDOT uses conventional lap splices whenever practical. Use the Standard Minimum Lap Splice Lengths shown in Figure 14.3-D for all tension and compression lap splices unless a longer splice length is required by calculation. It is NDOT practice to use as a minimum a Class B splice for #4 through #11 bars. Where feasible, stagger lap splices for main-member reinforcement such that no more than 50% are lapped in any one location. A minimum stagger of 2 ft between adjacent centerlines of splices is required for individual and bundled bars.

   If transverse reinforcing steel in a bridge deck is lapped near a longitudinal construction joint, the entire lap splice shall be placed on the side of the construction joint that will be poured last.

2. Mechanical Splices. (Reference: LRFD Article 5.10.8.4.2b). A second method of splicing is by mechanical splices, which use proprietary splicing mechanisms. Mechanical splices are appropriate away from plastic hinges and where interference problems preclude the use of more conventional lap splices, and in staged construction. Even with mechanical splices, it is frequently necessary to stagger splices. The designer must check clearances. In addition, fatigue shall be considered. Mechanical splices shall develop 125% of the bar yield strength for reinforcing steel in non-yielding areas. Mechanical splices shall develop 160% of the bar yield strength for reinforcing steel in yielding areas not subject to plastic hinging.

Bar Size	Area (in^2)	Diameter (in)	Class	Uncoated (in)	Epoxy Coated (in)
#4	0.20	0.500	B	20	24
#5	0.31	0.625	B	24	30
#6	0.44	0.750	B	30	34
#7	0.60	0.875	B	38	45
#8	0.79	1.000	B	48	57
#9	1.00	1.128	B	60	72
#10	1.27	1.27	B	74	88
#11	1.56	1.41	B	90	108

Note: Lap splice lengths based on f'_c= 4 ksi, f_y = 60 ksi, non-top bars, uncoated bars spaced at 4 inches or more with a clear cover of 1.5 inches or more, epoxy coated bars spaced at 6 bar diameters or more with a clear cover of 3 bar diameters or more, and normal weight concrete.

STANDARD MINIMUM SPLICE LENGTHS FOR BARS IN TENSION AND COMPRESSION

Figure 14.3-D

3. Welded Splices. Splicing of reinforcing bars by welding, although allowed by the *LRFD Specifications*, is seldom used by NDOT and not encouraged primarily because of quality issues with field welding. However, shop-fabricated, butt-welded hoops can be used as confinement reinforcement for columns. Welding of reinforcing steel is not addressed by the AASHTO/ANSI/AWS *D1.5 Bridge Welding Code*, and the designer must reference the current *Structural Welding Code — Reinforcing Steel* of AWS (D1.4).

4. Full Mechanical/Welded Splices. See LRFD 5.10.8.4.2b and 5.10.8.4.2c.

14.3.1.8.2 Plastic Hinge Regions

In columns and drilled shafts, there shall be no splices in the longitudinal reinforcing or splicing of spiral reinforcing within the plastic hinge regions. These regions shall be clearly identified in the contract documents.

14.3.1.9 Bundled Bars

Reference: LRFD Articles 5.10.8.2.3 and 5.10.8.4.2a

NDOT allows the use of two-bundled or three-bundled bars; NDOT prohibits the use of four-bundled bars.

The development length of bars within a bundle shall be taken as that of an individual bar as specified in Section 14.3.1.7, increased by 20% for a three-bar bundle.

Lap splices of bundled bars shall be based upon development lengths as specified above. Entire bundles shall not be lap spliced at the same location. Individual bars within a bundle may be lap spliced, but the splices shall not overlap. Fit and clearance of reinforcing shall be carefully checked by calculations and large-scale drawings.

14.5.2.1 Concrete Stress Limits

Reference: LRFD Article 5.9.2.3

Tensile stress limits for fully prestressed concrete members shall conform to the requirements for "Other Than Segmentally Constructed Bridges" in LRFD Article 5.9.2.3, except that the tensile stress at the Service limit state, after losses, shall be limited as follows: For components with bonded prestressing tendons or reinforcement, the tensile stress in the precompressed tensile zone shall be limited to:

$0.095\sqrt{f'_c}$ ≤ 0.2 ksi in the top of deck, slab, or girder and ≤ 0.3 ksi elsewhere