

BDM Revisions

7.4 Column Reinforcement

7.4.1 Reinforcing Bar Material

Steel reinforcing bars for all bridge substructure elements (precast and cast-in-place) shall be in accordance with [Section 5.1.2](#).

7.4.2 Longitudinal Reinforcement Ratio

The reinforcement ratio is the steel area divided by the gross area of the section (A_s/A_g). The maximum reinforcement ratio shall be 0.04 in SDCs A, B, C and D. The minimum reinforcement ratio shall be 0.007 for SDC A, B, and C and shall be 0.01 for SDC D.

For bridges in SDC A, if oversized columns are used for architectural reasons, the minimum reinforcement ratio of the gross section may be reduced to 0.005, provided all loads can be carried on a reduced section with similar shape and the reinforcement ratio of the reduced section is equal to or greater than 0.01 and $0.133f'/f_y$. The column dimensions are to be reduced by the same ratio to obtain the similar shape.

7.4.3 Longitudinal Splices

In general, no splices are allowed when the required length of longitudinal reinforcement is less than the conventional mill length of (typically 60-feet). Splicing of longitudinal reinforcement shall be outside the plastic hinge regions. But in SDC A, splices need only be located a minimum of 1.5 times the column diameter from the top and bottom of the column. The bridge plans shall clearly identify the limits of the permissible splice zone. [Figure 7.4.3-1](#) shows standard column reinforcement details.

For bridges in SDC's A and B, no lap splices shall be used for #14 or #18 bars. Either lap or mechanical splices may be used for #11 bars and smaller. Lap splices shall be detailed as Class B splices. The smaller bars in the splice determine the length of lap splice required. When space is limited, #11 bars and smaller can use welded splices, an approved mechanical butt splice, or the upper bars can be bent inward (deformed by double bending) to lie inside and parallel to the lower bars. The spacing of the transverse reinforcement over the length of a lap splice shall not exceed 4-inches or one-quarter of the minimum member dimension.

For bridge in SDC's C and D, bars shall be spliced using mechanical splices meeting the requirements of *Standard Specification* Section 6-02.3(24)F. Splices shall be staggered. The distance between splices of adjacent bars shall be greater than the maximum of 20 bar diameters or 24-inches.

crossbeam, provided that adequate transfer of column forces is provided.

For precast prestressed concrete girder bridges in SDCs C and D with two-stage fixed diaphragms at intermediate piers, all column longitudinal reinforcement should extend to the top of the cast-in-place concrete diaphragm (upper crossbeam) above the lower crossbeam. Careful attention should be given that column reinforcement does not interfere with extended strands projecting from the end of the prestressed concrete girders. In case of interference, column longitudinal reinforcement obstructing the extended strands may be terminated at top of the lower crossbeam, and shall be replaced with equivalent full-height stirrups extending from the lower to upper crossbeam within the effective width as shown in Figure 7.4.4-1. All stirrups within the effective zone, based on an approximate strut-and-tie model, may be used for this purpose. The effective zone shall be taken as column diameter plus depth of lower crossbeam provided that straight column bars are adequately developed into the lower crossbeam. The effective zone may be increased to the column diameter plus two times depth of lower crossbeam if headed bars are used for column longitudinal reinforcement.

If the depth of lower crossbeam is less than 1.25 times the tension development length required for column reinforcement, headed bars shall be used. Heads on column bars terminated in the lower crossbeam are preferable from a structural perspective. However, extra care in detailing during design and extra care in placement of the column reinforcement during construction is required. Typically the heads on the column bars will be placed below the lower crossbeam top mat of reinforcement. Headed reinforcement shall conform to the requirements of ASTM 970 Class HA.

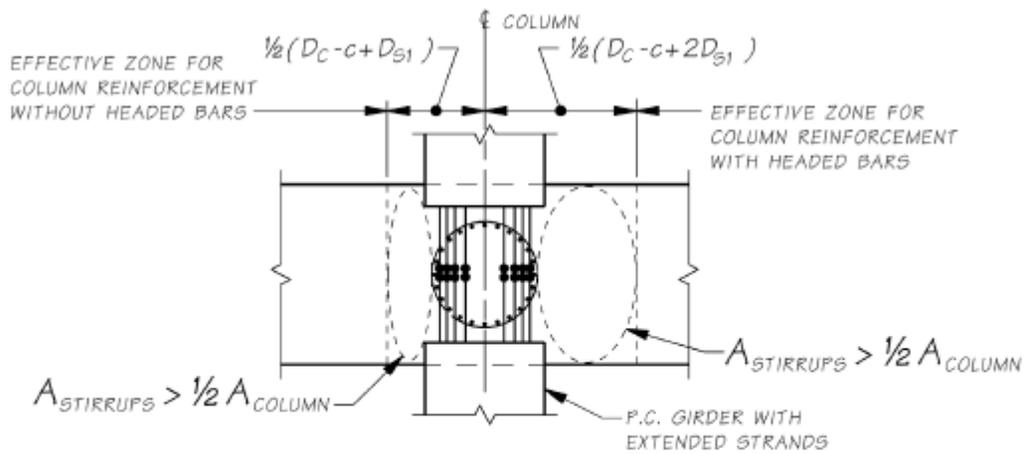
Transverse column reinforcement only needs to extend to the top of the lower crossbeam just below the top longitudinal steel. However, when the joint shear principal tension is less than $0.11\sqrt{f'_c}$, minimum cross tie reinforcement shall be placed acting across the upper cross beam in accordance with the AASHTO Seismic 8.13.3. The minimum cross tie reinforcement shall provide at least as much confining pressure at yield as the column spiral can provide at yield. This pressure may be calculated assuming hydrostatic conditions. If the joint shear principal tension exceeds $0.11\sqrt{f'_c}$, then additional joint reinforcement as outlined by AASHTO Seismic 8.13.3 shall be provided. With the exception of J-bars, the additional reinforcement shall be placed in the upper and lower crossbeam. The cross tie reinforcement may be placed with a lap splice in the center of the joint.

Large columns or columns with high longitudinal reinforcement ratios may result in closely spaced stirrups with little clear space left for proper concrete consolidation outside the reinforcement. In such cases, either hanger reinforcement comprised of larger bars with headed anchors may be used in the effective zone shown in Figure 7.4.4-1 or supplemental stirrups may be placed beyond the effective zone. Hanger reinforcement in the effective zone is preferred.

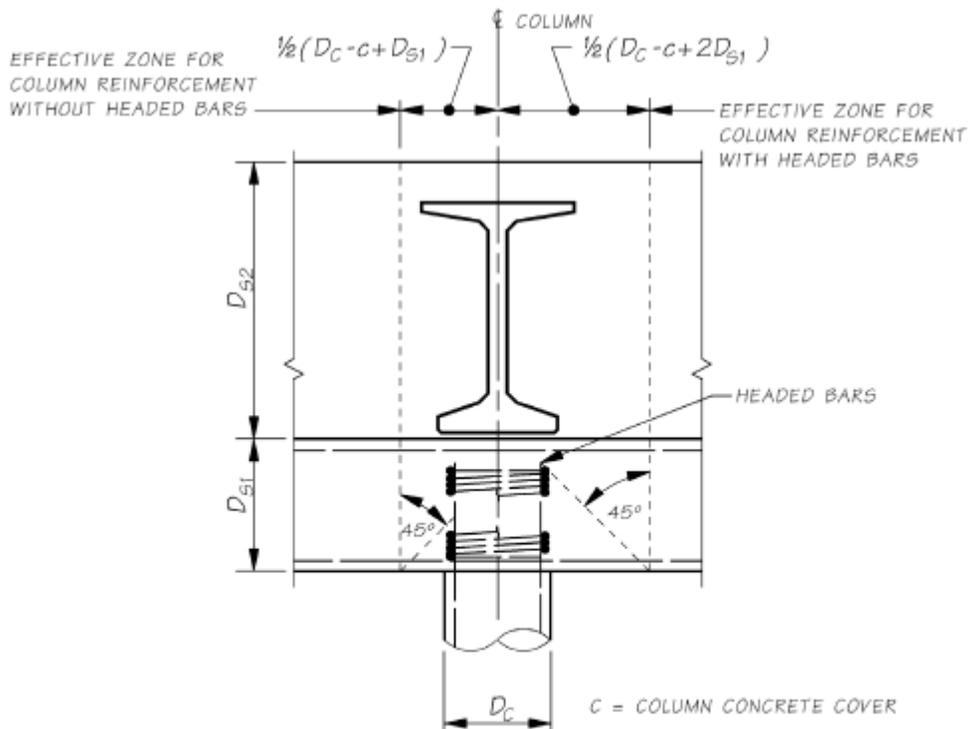
The designer is encouraged to include interference detail/plan views of the crossbeam reinforcement in relation to the column steel in the contract drawings. Suggested plans

include the views at the lower stage crossbeam top reinforcement and the upper crossbeam top reinforcement.

- B. **Footings** – Longitudinal reinforcement at the bottom of a column should extend into the footing and rest on the bottom mat of footing reinforcement with standard 90° hooks. In addition, development of longitudinal reinforcement shall be in accordance with AASHTO Seismic 8.8.4 and AASHTO LRFD 5.11.2.1. Headed bars may be used for longitudinal reinforcement at the bottom of columns. The head shall be placed at least 3-inches below the footing bottom mat reinforcement. This may require the footing to be locally thickened in the region of the column to provide cover for the bottom of the headed bars.



PLAN



ELEVATION

Longitudinal Development Into Crossbeams

Figure 7.4.4-1

- C. **Shafts** – Column longitudinal reinforcement in shafts is typically straight. Embedment shall be a minimum length equal to $l_{ns} = l_s + s$ (per TRAC Report WA-RD 417.1 titled

“Noncontact Lap Splices in Bridge Column-Shaft Connections”).

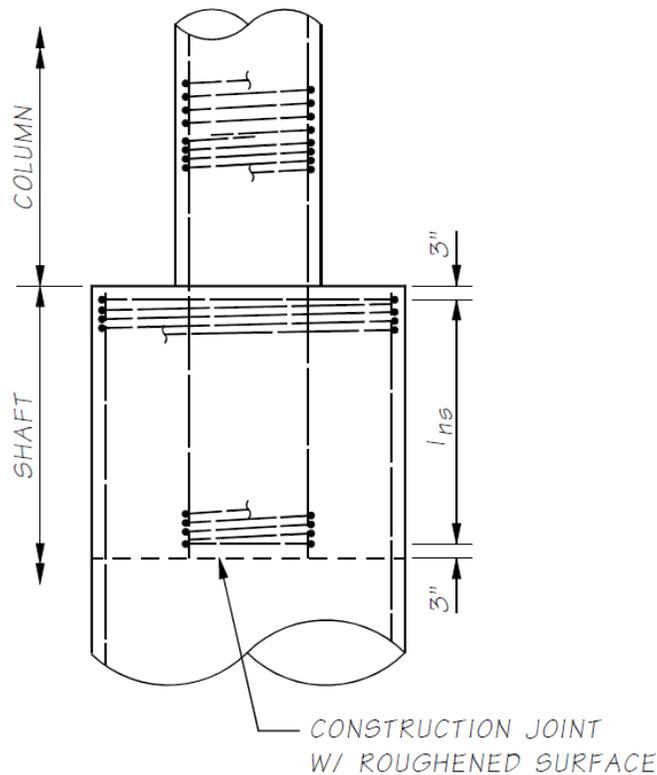
Where:

- l_s = the larger of $1.7 \times l_{ac}$ or $1.7 \times l_d$ (for Class C lap splice) where:
- l_{ac} = development length from the Seismic Guide Spec. 8.8.4 for the column longitudinal reinforcement.
- l_d = tension development length from AASHTO LRFD Section 5.11.2.1 for the column longitudinal reinforcement.
- s = distance between the shaft and column longitudinal reinforcement

The requirements of the AASHTO Seismic 8.8.10 for development length of column bars extended into oversized pile shafts for SDC C and D shall not be used.

All applicable modification factors for development length, except one, in AASHTO LRFD 5.11.2 may be used when calculating l_d . The modification factor in 5.11.2.1.3 that allows l_d to be decreased by the ratio of $(A_s \text{ required})/(A_s \text{ provided})$, shall not be used. Using this modification factor would imply that the reinforcement does not need to yield to carry the ultimate design load. This may be true in other areas. However, WSDOT shaft/column connections are designed to form a plastic hinge, and therefore the reinforcement shall have adequate development length to allow the bars to yield.

See Figure [7.4.4-2](#) for an example of longitudinal development into shafts. Section 7.8.2-K provides additional requirements for transverse shaft reinforcement to confine the non-contact lap splice.



Longitudinal Development Into Shafts

Figure 7.4.4-2

7.4.5 Transverse Reinforcement

A. **General** – All transverse reinforcement in columns shall be deformed. Although allowed in the AASHTO LRFD Specification, plain bars or plain wire may not be used for transverse reinforcement.

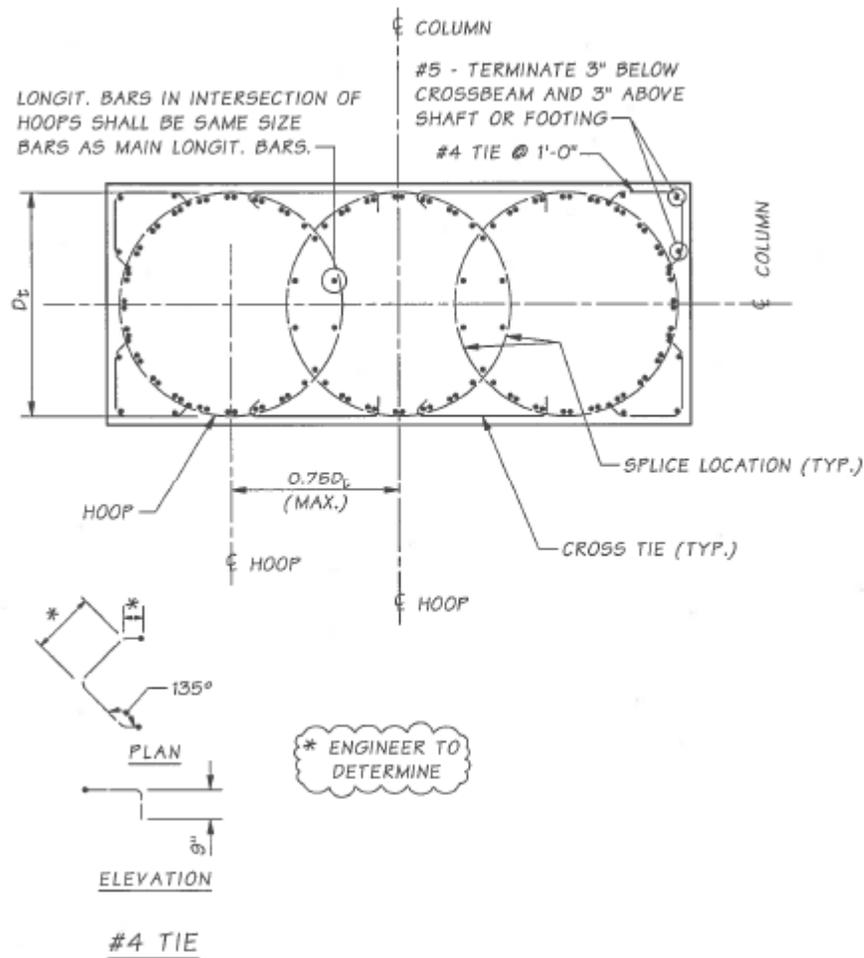
Columns in SDCs A and B may use spirals, circular hoops, or rectangular hoops and cross-ties. Spirals are the preferred confinement reinforcement and shall be used whenever a #6 spiral is sufficient to satisfy demands. When demands require reinforcement bars greater than #6, circular hoops of #7 through #9 may be used. Bundled spirals shall not be used for columns or shafts. Also, mixing of spirals and hoops within the same column is not permitted by the AASHTO Seismic Specifications. Figure 7.4.5-1 and 7.4.5-2 show transverse reinforcement details for rectangular columns in high and low seismic zones, respectively.

Columns in SDCs C and D shall use circular hoop reinforcement where possible, although rectangular hoops with ties may be used when large, odd shaped column sections are required. Where the column diameter is 3-feet or less, the WSDOT Steel Specialist shall be contacted regarding the constructability of smaller diameter welded hoops.

When rectangular hoops with ties are used, consideration shall be given to column

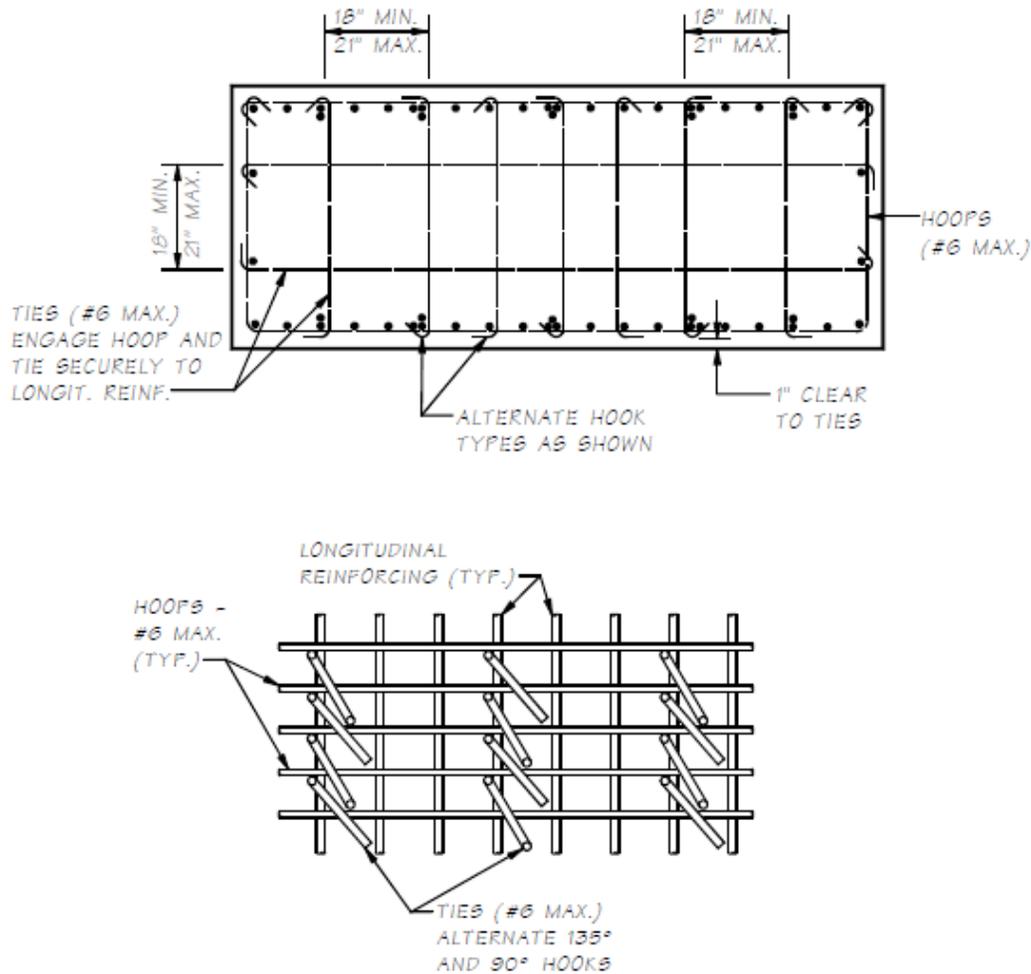
constructability. Such considerations can include, but are not limited to a minimum of 2'-6" by 3'-0" open rectangle to allow access for the tremie tube and construction workers for concrete placement, in-form access hatches, and/or external vibrating.

A larger gap between transverse reinforcement should be provided at the top of columns to allow space for the crossbeam longitudinal reinforcement to pass. In SDC's C & D, the gap shall not exceed the maximum spacing for lateral reinforcement in plastic hinge regions specified in AASHTO Seismic 8.8.9. This can be of particular concern in bridge decks with large superelevation cross slopes.



Constant and Tapered Rectangular Column Section SDCs C and D

Figure 7.4.5-1



Constant and Tapered Rectangular Column Section SDCs A and B

Figure 7.4.5-2

- B. **Spiral Splices and Hoops** – Welded laps shall be used for splicing and terminating spirals and shall conform to the details shown in Figure 7.4.5-3. Only single sided welds shall be used, which is the preferred method in construction. Spirals or butt-welded hoops are required for plastic hinge zones of columns. Lap spliced hoops are not permitted in columns in any region.

Although hooked lap splices are structurally acceptable, and permissible by AASHTO LRFD Specification for spirals or circular hoops, they shall not be allowed due to construction challenges. While placing concrete, tremies can get caught in the protruding hooks, making accessibility to all areas and its withdrawal cumbersome. It is also extremely difficult to bend the hooks through the column cage into the core of the column.

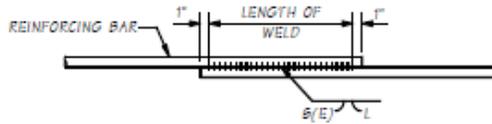
When welded hoops are used, the plans shall show a staggered pattern around the perimeter of the column so that no two adjacent welded splices are located at the same location. Also, where interlocking hoops are used in rectangular or non-circular columns, the splices shall be

located in the column interior.

Circular hoops for columns shall be shop fabricated using a manual direct butt weld or resistance butt weld. Currently, a Bridge Special Provision has been developed to cover the fabrication requirements of hoops for columns and shafts, which may eventually be included in the *Standard Specifications*. Manual direct butt welded hoops require radiographic nondestructive examination (RT), which may result in this option being cost prohibitive at large quantities.

Columns with circular hoop reinforcement shall have a minimum 2" concrete cover to the hoops to accommodate resistance butt weld "weld flash" that can extend up to ½" from the bar surface.

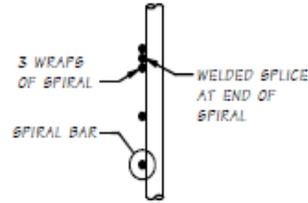
Field welded lap splices and termination welds of spirals of any size bar are not permitted in the plastic hinge region including a zone extending 2'-0" into the connected member and should be clearly designated on the contract plans. If spirals are welded while in place around longitudinal steel reinforcement, there is a chance that an arc can occur between the spiral and longitudinal bar. The arc can create a notch that can act as a stress riser and may cause premature failure of the longitudinal bar when stressed beyond yield. Because high strains in the longitudinal reinforcement can penetrate into the connected member, welding is restricted in the first 2'-0" of the connected member as well. It would be acceptable to field weld lap splices of spirals off to the side of the column and then slide into place over the longitudinal reinforcement.



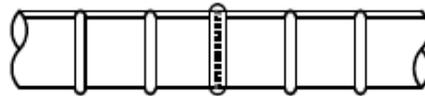
WELDED LAP SPlice DETAIL

WELDED LAP SPlice IS SUITABLE FOR SPIRALS IN COLUMNS AND SHAFTS UP TO BAR SIZE #6. LAP SPlice FOR BAR SIZES #7 TO #9 ARE ONLY INTENDED FOR SHAFT HOOPS. WELDING SHALL MEET THE REQUIREMENTS OF STD. SPEC. 6-02.3(24)E. FOR WELD DIMENSIONS, SEE TABLE BELOW.

SPIRALS	BAR SIZE	WELD DIMENSIONS (IN)		
		B	E	L (LENGTH)
	#4	1/4	1/8	4
	#5	3/8	3/16	6
	#6	3/8	3/16	6
HOOPS FOR SHAFTS	#7	3/8	1/4	7
	#8	1/2	1/4	8
	#9	3/4	3/8	8

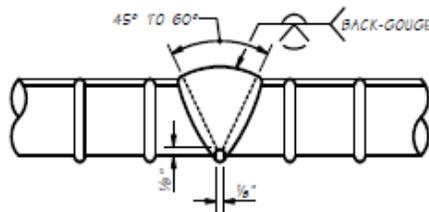


SPIRAL TERMINATION DETAIL

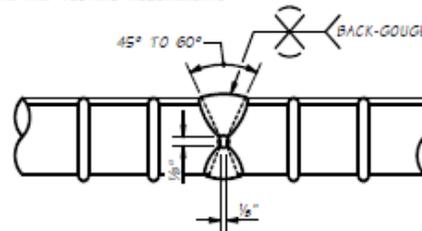


RESISTANCE BUTT JOINT DETAIL

SEE SPECIAL PROVISIONS FOR APPROVAL AND TESTING REQUIREMENTS



SINGLE V-GROOVE WELD
AWS D1.4 FIGURE 3.2(A)



DOUBLE V-GROOVE WELD
AWS D1.4 FIGURE 3.2(B)

MANUAL DIRECT BUTT JOINT DETAILS

ALL BACKING SHALL BE REMOVED.
SEE SPECIAL PROVISIONS FOR RT TESTING FREQUENCY

Welded Spiral Splice and Butt Splice Details

Figure 7.4.5-3

	Name	Approval Signature	Date
Revision Author	Bijan Khaleghi		3/10/2014
Revision Checker	Chyuan-Shen Lee Geoff Swett		4/1/2014
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BDM Coordinator	Scott Sargent		
Check of Revised Sheets	Mike Bauer		
<p>Revision Description:</p> <p>This memorandum revises WSDOT column reinforcement in accordance with AASHTO LRFD SGS requirements, and in accordance with knowledge acquired from the January 2014 NHI Seismic Training course in Washington.</p>			