REVISIONS TO THE SCDOT SEISMIC DESIGN SPECIFICATIONS FOR HIGHWAY BRIDGES

January 2025

The revisions included herein shall apply to the SCDOT Seismic Design Specification for Highway Bridges and they supersede Bridge Design Memorandum DM0115.

REVISIONS TO SECTION 2

2.2 NOTATION:

On Page 2-5, replace

> *h* Height from MSA point of fixity to top of column

with

> *h* Clear height of column from top of footing to top of column or height from MSA point of fixity to top of column/pile (ft)

REVISIONS TO SECTION 3

Table 3.1 Bridge Operational Classification (OC)

Replace the top line for the description of OC I with the following:

> All bridges (including ramp and collector-distributor bridges that carry system-to-system movements) that are located on the interstate system or along the following roads:

Table 3.4 Bridge Components (Local) Damage Level Objectives:

Replace Reference Note 3 with:

3. Include Bent Caps, Footings (including the piles supporting the footings), and Oversized Drilled Shafts

3.5 SEISMIC DESIGN CATEGORY (SDC)

Delete last sentence of first paragraph and replace it with:

> Use the flow chart in Figure 3.1 to determine the SDC for a structure.

3.6 SEISMIC DEMAND

Delete the second paragraph and replace it with:

> Displacement demand can be obtained from a Multimode Spectral Analysis (MSA). Section 5 covers displacement demand modeling and computations.

Table 3.6 Bridge System Seismic Displacement Performance Limits

Delete this table.

3.11 DESIGN REQUIREMENTS FOR TEMPORARY BRIDGES AND STAGED CONSTRUCTION

Delete the last paragraph and replace it as follows:

> The following applies to widening of existing bridges. If the bridge has been seismically designed using the 2001 Seismic Design Specifications for Highway Bridges or the 2008 Seismic Design Specifications for Highway Bridges, the widened structure shall be designed to meet the same seismic performance requirements as the existing bridge. For widening of existing bridges that were not seismically designed using the above specifications, seismic design is not required.

3.12 DESIGN REQUIREMENTS FOR PEDESTRIAN BRIDGES

Delete the subsection and replace it with the following:

> **3.12 DESIGN REQUIREMENTS FOR NON-HIGHWAY BRIDGES**
>
> Pedestrian and Utility bridges over roads carrying vehicular traffic shall satisfy OC III performance objectives as indicated in Table 3.3. Pedestrian bridges owned or maintained by the Department or located within Department right-of-way will also satisfy the OC III performance objectives.
>
> Railroad bridges over roads carrying vehicular traffic shall satisfy the requirements of AREMA Chapter 9 for life safety and any other AREMA or railroad specific requirements.

3.13.1 Seismic Design Category A and Single Span Bridges

Delete next to last sentence of first paragraph and replace it with:

> See Figure 3.2 for the SDC A analysis and design flowchart.

3.13.2 Seismic Design Category B

Delete next to last sentence of first paragraph and replace it with:

> See Figure 3.3 for the SDC B analysis and design flowchart.

3.13.3 Seismic Design Category C

Delete next to last sentence of first paragraph and replace it with:

> See Figure 3.4 for the SDC C analysis and design flowchart.

3.13.4 Seismic Design Category D

Delete next to last sentence of first paragraph and replace it with:

> See Figure 3.5 for the SDC D analysis and design flowchart.

<u>REVISIONS TO SECTION 5</u>

5.1.8 Load Combinations

Delete the second paragraph and replace it with:

> 50% of Live load without impact shall be included in the load combination. The Live load shall be distributed evenly along the bridge center line to analyze the seismic response of foundation.

Add Section 5.2.5 Accounting for Structure Resonances

Add:

> The Structure Engineer of Record shall consider potential resonances of the bridges due to coincidences of the structure fundamental period, the soil column period and the earthquake period according to LRFD Seismic Analysis and Design of Transportation Geotechnical Features and Structural Foundations, FHWA-NHI-11-032, GEC No.3. Acceptable solutions to address large displacement demand due to resonances include changing structural configuration to avoid resonant responses and/or designing and detailing bridge structure elements to sustain the high demand.

5.6.2 Backwall/Wingwall Modeling

Delete the subsection and replace it with:

> Backwall and wingwall stiffness shall be modeled to account for the mobilized passive resistance due to soil-structure interaction per the GDM.

<u>**REVISIONS TO SECTION 6**</u>

6.2 DEFINITION OF PLASTIC HINGES

Replace equation (6-3) with:

$$L_p = D^* + 0.08H' \leq 1.5D^*$$

6.4 PLASTIC HINGE ACCESSIBILITY

Delete the last paragraph and replace it with the following:

> The key to forcing the plastic hinge above ground with the oversized drilled shaft is designing the transverse reinforcement in the shaft with a larger diameter than the column framing into the shaft. Providing a larger diameter of transverse reinforcement increases the area of confined concrete in the region. Oversized drilled shafts shall be at least 24 inches larger than the diameter of the column framing into the shaft. Column longitudinal reinforcement shall extend into oversized drilled shafts in a staggered manner as shown in Figure 6.2.

Figure 6.2 Typical and Oversized Drilled Shafts

Delete the elevation view of the Oversized Drilled Shaft in the figure and replace it with the following:

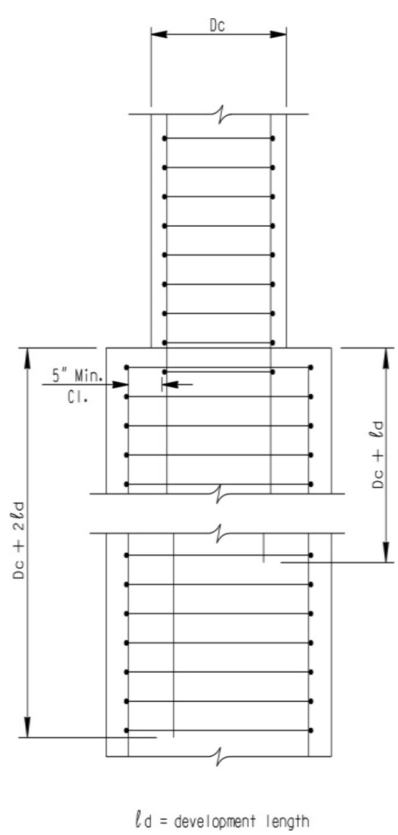


Figure 6.2 Oversized Drilled Shaft

6.5.2 Member Displacement Capacity is revised as follows:

Delete the first paragraph and replace it with the following:

> The displacement capacity of a member is based on its rotation capacity, which in turn is based on its curvature capacity. The curvature capacity shall be determined by moment curvature analysis, see Section 6.7. The local displacement capacity (disregarding movement of surrounding soils and assuming fixed at the point of fixity), Δ_c, of any prismatic column/pile may be idealized as displacement of one or two cantilever segments presented in Equations 6-5 to 6-8 and 6-9 to 6-18, respectively. See Figures 6.3 to 6.6 for details. Figures 6.5 and 6.6 are for typical drilled shaft foundation if point of fixity can be forced above the drilled Shaft. If for any reason the column/shaft can't be considered as prismatic with regard to section properties down to the point of fixity, such as oversized drilled shaft supporting columns or steel construction casing is used for non-oversized drilled shaft, and the point of fixity falls below the point where section property changes, the designer shall consider the effect of different moment curvature along the depth. Refined analysis with pushover models (assuming fixed at POF and disregarding the surrounding soils) shall be performed for this type of conditions or other complex conditions not covered here.

Delete Equation (6-6) and replace it with the following:

$$\Delta_y = \frac{1}{3}\phi_y (L + L_{sp})^2 \qquad \text{Where } L_{sp} = 0.15 f_{ye} d_{bl}$$

L_{sp} = Strain Penetration

Delete Equation (6-17) and replace it with the following:

$$\Delta_{y_1} = \frac{1}{3}\phi_{y_1} (L_1 + L_{sp})^2$$

Delete Equation (6-18) and replace it with the following:

$$\Delta_{y_2} = \frac{1}{3}\phi_{y_2} (L_2 + L_{sp})^2$$

6.5.3 Simplified Displacement Capacity for SDC B Bridges

Delete the first paragraph and replace it with the following:

> For SDC B bridges with column/drilled shaft bents or prestressed concrete piles, if these foundation members can be considered prismatic from the top to the depth of point of fixity, the global displacement capacity of each bent may be estimated conservatively with the local displacement (by ignoring the effects of surrounding soil), by either using Equation 6-19 or the Equations given in Section 6.5.2:

Replace

h Clear height of column (ft)

With

h Clear height of column from top of footing to top of column or height from MSA point of fixity to top of column / pile (ft)

Add the following paragraph to the end of the Section:

Perform refined analysis to determine local and global displacements with push over models for other substructure configurations.

6.5.4 Simplified Yield Displacement for SDC B Bridges

Delete the section title and replace it with the following: "**Simplified Global Yield Displacement for SDC B Bridges"**

Revise the first paragraph as:

For SDC B bridges, the global yield displacement for each bent may be estimated using Either Equation 6-23 or the equations presented in Section 6.5.2.

Revise Equation 6-21 to the following:

$$\Delta_y = \frac{M_p L_y^2}{\Psi E_{ce}}$$

Delete the definition of variable for Modulus of elasticity (E) and replace it with the following:

E_{ce} Modulus of elasticity for column, pile or drilled shaft using expected material properties (ksi)

Add the following paragraph to the end of the Section:

Perform refined analysis to determine local and global yield displacement with push over models for other substructure configurations.

6.6.5 Confined Concrete Model

Delete Equation (6-46) and replace it with the following:

$$\varepsilon_{ccu} = 0.004 + \frac{1.4 f_{yh} \rho_s \varepsilon_{su}^R}{f'_{cc}}$$

6.9 REQUIREMENTS FOR CAPACITY PROTECTED COMPONENTS

Third line of the second paragraph, add "elastic" after "essentially".

REVISIONS TO SECTION 7

7.1.3 Ductility Capacity

Delete the subsection and replace it with the following:

7.1.3 Local Member Ductility Capacity

Local member ductility is different from global ductility. The global ductility capacity is calculated by the global displacements, which include the effects of soil movement. The local ductility capacity of a member is defined using Equations 7-3a or 7-3b with the idealized local displacements. The local displacement ductility capacity shall be calculated with methodology given in Section 6.5.2

$$\mu_c = \frac{\Delta_c}{\Delta_y} \text{ for Free Head condition} \qquad (7\text{-}3a)$$

$$\mu_{c1} = \frac{\Delta_{c1}}{\Delta_{y1}} \ \& \ \mu_{c2} = \frac{\Delta_{c2}}{\Delta_{y2}} \text{ for Fixed Head condition} \qquad (7\text{-}3b)$$

Where:

μ_c is the local member ductility capacity, see Figure 6.3 & 6.5 (dimensionless)

μ_{c1} is the local member ductility capacity of first cantilever segment, see Figure 6.4 & 6.6 (dimensionless)

μ_{c2} is the local member ductility capacity of second cantilever segment, see Figure 6.4 & 6.6 (dimensionless)

$\Delta_c, \Delta_{c1}, \Delta_{c2}, \Delta_y, \Delta_{y1}, \Delta_{y2}$ are the idealized local member displacements calculated by the equations given in Section 6.5.2 or equivalent values obtained from refined analysis when disregarding the displacement of foundations in soil from point of fixity downward and all surrounding soils (in)

Each interior bent or end bent shall have a minimum local member ductility capacity of 3 to ensure dependable rotational capacity in the plastic hinge regions regardless of the displacement demand imparted to that member. This requirement does not apply to precast concrete pile bents supporting flat slab bridges, when the RFP allows below-ground plastic hinging.

Table 7.1 Substructure Unit Quantitative Damage Criteria (Maximum Ductility Demand μ_d)

Delete the table and replace it with the following:

Bridge System		Design Earthquake	Operational Classification (OC)		
			I	**II**	**III**
Superstructure		**FEE**	1.0	1.0	See Note
		SEE	1.0	1.0	1.0
Substructure	**Prestressed Concrete Pile Interior Bents**	**FEE**	1.0	2.0	See Note
		SEE	2.0	4.0	4.0
	Prestressed Concrete Pile End Bents	**FEE**	1.0	2.0	See Note
		SEE	2.0	4.0	4.0
	Single Column Bents	**FEE**	1.0	2.0	See Note
		SEE	2.0	3.0	4.0
	Multi Column Bents	**FEE**	2.0	3.0	See Note
		SEE	4.0	6.0	6.0
	Pier Walls Weak Axis	**FEE**	2.0	3.0	See Note
		SEE	3.0	5.0	5.0
	Pier Walls Strong Axis	**FEE**	1.0	1.0	See Note
		SEE	1.0	1.0	1.0

Note: Analysis for FEE is not required for OC III bridges.

<u>REVISIONS TO SECTION 8</u>

8.1 SDC A AND SINGLE SPAN BRIDGES MINIMUM REQUIREMENTS

Delete the last sentence of the second paragraph and replace it with the following:

> See Figures 8.2, 8.3, and 8.4 for details.

Add the following to the end of the section:

The minimum anchorage length requirement of longitudinal reinforcement in Section 8.4.6 and 8.4.7 also apply to SDC A bridges.

8.4 DUCTILE MEMBER DESIGN REQUIREMENTS FOR SDC B, C AND D

Delete the paragraph and replace it with the following:

The provisions of this section are required for bridges designated SDC B, C and D with the exception of the minimum detailing requirements as shown in Figures 8.2, 8.3, 8.4 and related sub-sections, which are applicable to all bridges.

8.4.5 Splicing of Longitudinal Reinforcement in Columns

Replace subtitle and first sentence of section 8.4.5 with the following:

8.4.5 Splicing of Longitudinal Reinforcement in Columns and Drilled Shafts

Splicing of longitudinal column and drilled shaft reinforcement, subject to ductility demand greater than 1.0, shall be outside the plastic hinging region as provided in Section 6.4.

8.4.6 Minimum Development Length of Longitudinal Column Reinforcement

Replace the subsection title with "**Minimum Anchorage Length of Longitudinal Column Reinforcement**"

Delete Equation (8-5) and notations and replace with the following:

$$l_{acmin} = 24\ d_{bl} \qquad (8\text{-}5)$$

Where:

l_{acmin} Required minimum anchorage length for longitudinal column reinforcement (in), see Figure 8.2, 8.3 and 8.4

d_{bl} Longitudinal reinforcement nominal bar diameter (in)

8.4.9 Minimum Development Length of Longitudinal Column Reinforcement Extended into Oversized Shafts

Delete the paragraph and replace it with the following:

Longitudinal column reinforcement shall be extended into oversized shafts in a staggered manner with the minimum embedment lengths of ($D_c + l_d$) and ($D_c + 2l_d$), where D_c is the cross sectional dimension of the column and l_d is the tension development length of the longitudinal column reinforcement. See Figures 6.2 and 8.4.

8.4.10 Transverse Reinforcement Inside the Plastic Hinge Region

Delete the last sentence of the first paragraph and replace it with the following:

> The quantity of the transverse reinforcement required in the plastic hinge regions adjacent to interfaces between column /cap, column/footing, drilled shaft/ footing, cap/steel pipe pile infill is specified in section 8.7.7.

8.4.11 Transverse Reinforcement Outside the Plastic Hinge Region

Delete the paragraph and replace it with the following:

> The spacing of transverse reinforcement detailed outside of a column or non-oversized drilled shaft plastic hinge region shall not be more than twice that placed in the plastic hinge region.

8.4.12 Maximum Spacing for Transverse Reinforcement

Delete the last sentence and replace it with the following:

> The maximum spacing for transverse reinforcement outside the plastic hinge region for columns and non-oversized drilled shafts shall not exceed 12 inches.
>
> Bundled hoops are limited to 2 bars per bundle.

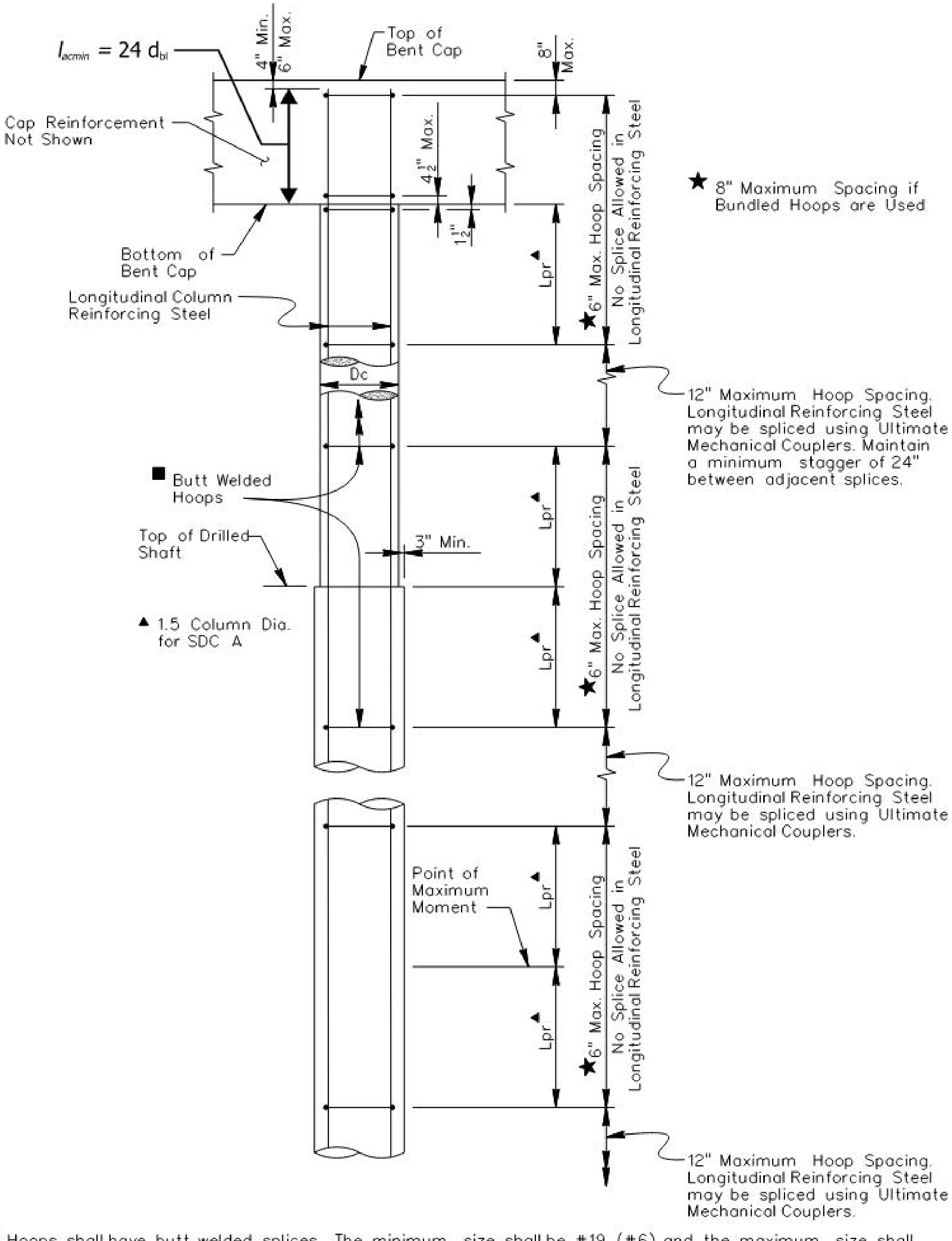
8.4.14 Transverse Confinement for Oversized Drilled Shafts

Delete the first sentence and replace it with the following:

> The volumetric ratio of lateral confinement in an oversized drilled shaft shall be at least 50% of the confinement at the base of the column. The shaft is designed for a loading case with the expected flexural nominal capacity equal to 1.25 times the moment demand generated by the overstrength moment of the column acting at the base of the column.

Figure 8.2 Transverse Reinforcement for Column on Non-oversized Drilled Shaft

Delete the figure and replace it with the following:

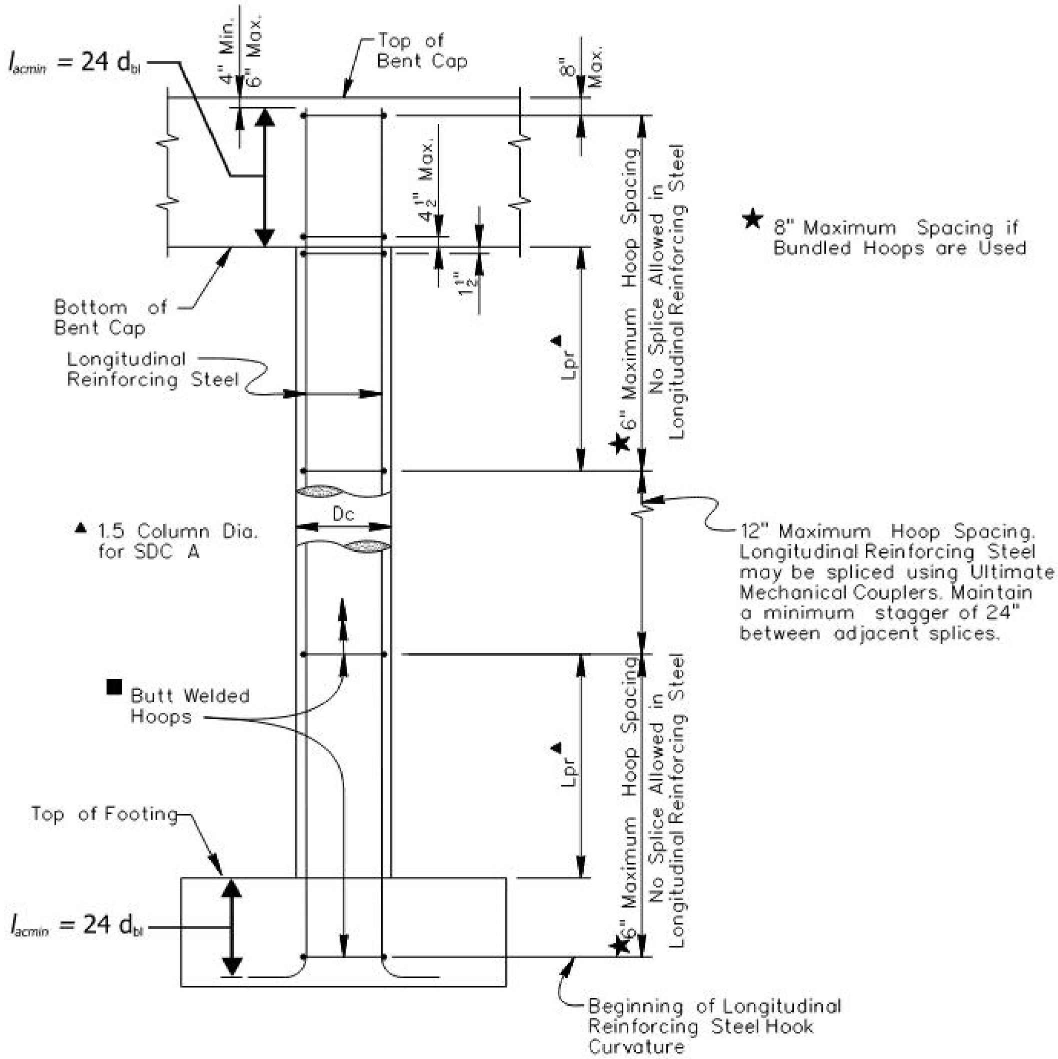


■ Hoops shall have butt welded splices. The minimum size shall be #19 (#6) and the maximum size shall be #25 (#8). To prevent the hoop weld splices from being located on the same vertical plane, the locations of the splices shall be staggered around the perimeter of the column by a minimum distance of 1/3 of the hoop circumference.

Figure 8.2 Transverse Reinforcement for Column on a Non–oversized Drilled Shaft

Figure 8.3 Transverse Reinforcement for Column on a Pile Footing

Delete the figure and replace it with the following:

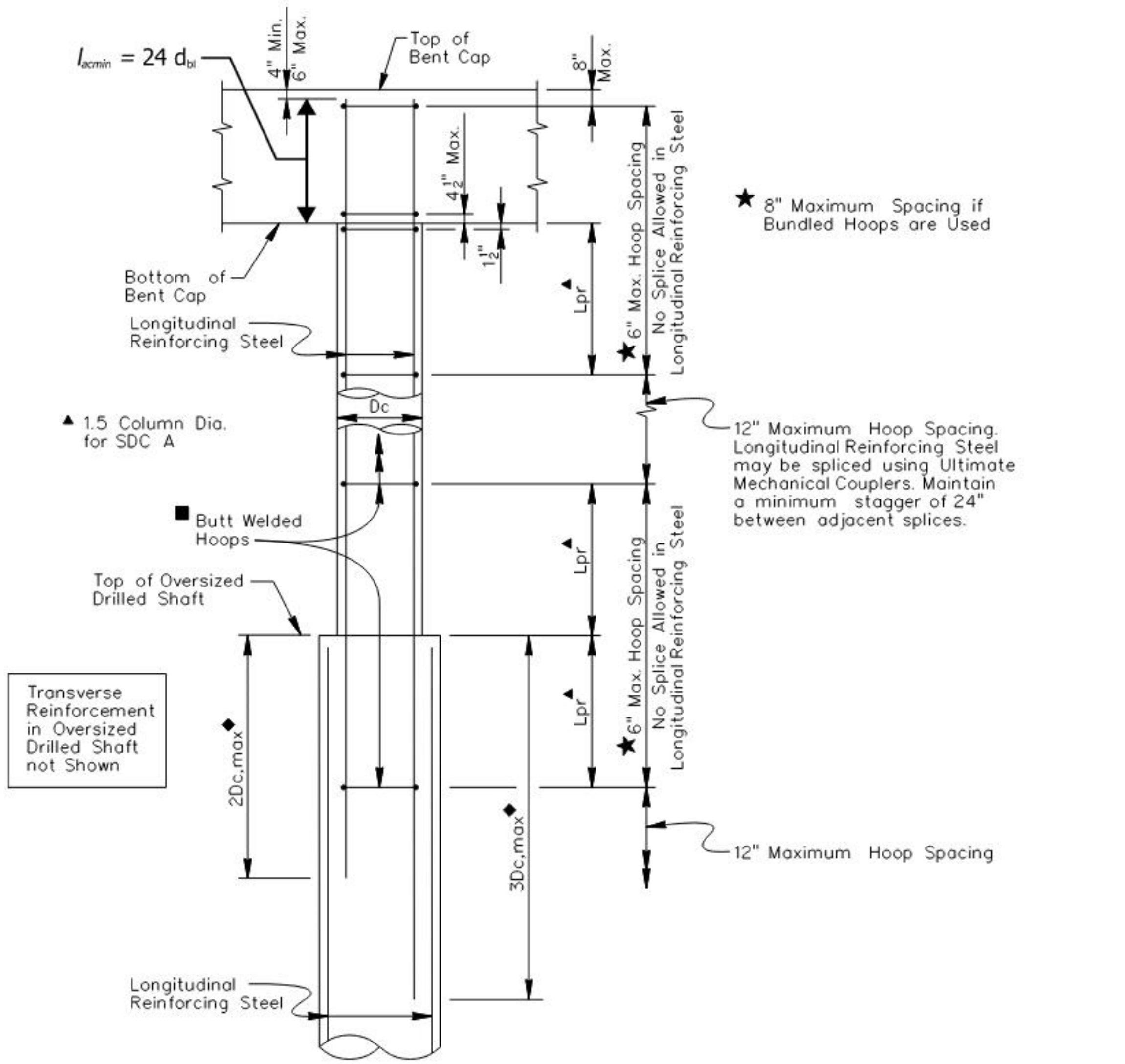


■ Hoops shall have butt welded splices. The minimum size shall be #19 (#6) and the maximum size shall be #25 (#8). To prevent the hoop weld splices from being located on the same vertical plane, the locations of the splices shall be staggered around the perimeter of the column by a minimum distance of 1/3 of the hoop circumference.

Figure 8.3 Transverse Reinforcement for a Column on a Pile Footing

Figure 8.4 Transverse Reinforcement for Column on an Oversized Drilled Shaft

Delete the figure and replace it with the following:



◆ Dc,max is the largest cross sectional dimension of the column.

■ Hoops shall have butt welded splices. The minimum size shall be #19 (#6) and the maximum size shall be #25 (#8). To prevent the hoop weld splices from being located on the same vertical plane, the locations of the splices shall be staggered around the perimeter of the column by a minimum distance of 1/3 of the hoop circumference.

Figure 8.4 Reinforcement for Column on Oversized Drilled Shaft

Note: Shaft transverse reinforcement does not have the same diameter as the column transverse reinforcement

8.6 SHEAR DESIGN

Revise the section title to "**SHEAR DESIGN FOR SDC B,C,D**"

Add the following before the first paragraph:

> Seismic shear capacity shall be based on the nominal material strengths, not the expected material strengths.

Replace

> V_c Concrete shear capacity (Section 8.6.1 or 8.6.2) (k)

with

> V_c Concrete shear capacity (Section 8.6.1) (k)

Replace

> V_s Reinforcement shear capacity (k) (Section 8.6.3)

with

> V_s Reinforcement shear capacity (Section 8.6.2) (k)

8.6.1 Concrete Subject to Flexure and Compression

Delete Equation (8-12b). Delete definition for A_{sp}. Add the following:

> ρ_s Volumetric ratio of transverse reinforcement (Eq. 6-44)

Replace

> μ_d Maximum local displacement ductility of member

with

> μ_d Maximum local displacement demand ductility of member, as defined by Equation 7-2

8.7.2 Maximum Allowable Principal Stress

> Replace "f'c" with "f'ce" in Equations 8-23 and 8-24.
>
> Revise definition under Equation 8-23 and 8-24 to define "f'ce" as "Expected maximum concrete compressive strength (ksi)"

8.7.3 Minimum Required Horizontal Reinforcement:

Delete the first paragraph and add the following:

When the principal tension stress is less than the limit established by Equation 8-25, a minimum amount of joint shear reinforcement in the form of column hoops, as determined by Equation 8-26, shall be detailed. Otherwise, the provisions of Sections 8.7.5 through 8.7.7 shall also apply.

8.7.7 Hoop Transverse Confinement Reinforcement

Replace

l_{ac} Required anchorage length for longitudinal column reinforcement (in)

with

l_{ac} Provided anchorage length for longitudinal column reinforcement (in)

8.7.8 Knee Joints

Add the following sentence behind the second sentence of the second paragraph:

The couplers shall be staggered at 2 ft minimum along the cap. The skin reinforcement can be lap spliced or mechanically coupled with "service level" couplers and the splice shall be staggered at 2 ft minimum along the cap.

<u>REVISIONS TO SECTION 9</u>

9.2 LONGITUDINAL AND TRANSVERSE CONNECTIONS

Add the following paragraphs at the beginning of the section:

The connection components between superstructures and substructures include anchor bolts, shear keys, dowel bars, retainer blocks, and back walls. For each individual bent, there are two seismic design strategies for these connection components. It is the engineer's decision to choose which strategy to use for a specific bent.

The first design strategy is to design the connection to sustain and transfer all seismic loads to the substructures and foundations. The substructures and foundations are then designed to sustain the seismic loads transferred from the superstructure and satisfy the design criteria.

The other design strategy is to design the connection components to sustain limited seismic loads and allow them to fuse, so that the substructures and foundations are able to sustain the limited seismic loads transferred from the superstructure and still satisfy the design criteria. In this case, the upper limit of the load capacity of the connection components is governed by the load capacity of the substructures and foundations.

Replace the existing first paragraph with the following:

When these components are designed to sustain the seismic shear loads, the combination of anchor bolts, dowel bars, back wall and/or shear keys, shall be designed to satisfy Equation 9-3 in both the longitudinal and transverse directions for bridges of any SDC.

Revise Equation (9-3) notations as:

$\boldsymbol{V_{sk}}$ Sum of shear strength of shear keys (including retainer blocks) (K)

$\boldsymbol{V_{ab}}$ Sum of Shear strength of anchor bolts (K)

$\emptyset_v$ Shear strength reduction factor, use 1.0

9.2.1 Anchor Bolt Design

Add the following paragraph to the end of this section:

Anchor bolts shall also be checked for moment resistance to make sure shear, instead of moment capacity governs failure of anchor bolts. Build down blocking might be needed if the bearings are too thick to prevent failure governed by moment.

9.2.2 Concrete Superstructure Shear Key Design

Add the following before the first paragraph:

Shear keys shall be provided at bents with expansion joints for SDC B, C, and D bridges.

Delete the last paragraph and add the following:

Shear keys should be proportioned so that the height of the shear key, or distance from top of load application to top of bent cap, shall not exceed 0.3 times the shear key dimension perpendicular to the center line of the beam. If for any reason the 0.3 ratio limit cannot be satisfied, the shear key shall be designed with adequate moment resistance no matter which design strategy is used for the shear key design.

The dimension of the shear key parallel to the center line of the beam shall be detailed as long as possible.

Adequate contact area shall be detailed between the shear key and the diaphragm for load transfer. The diaphragm shall also be designed to sustain the loads due to interaction with the shear key.

Closed cell extruded polystyrene foam shall be used to fill the gaps between the shear key and the diaphragm. See Figure 9.2 for shear key detailing requirements.

9.2.3 Steel Superstructure Shear Key Design

Add the following before the first paragraph:

Shear keys shall be provided at bents with expansion joints for SDC B, C, and D bridges.

9.2.4 Integral Backwall Design:

Delete the first paragraph and replace with the following:

For integral end bents, the lateral seismic forces are transmitted to the piles in part by the reinforcement connecting the superstructure to the end bent cap. This integral backwall shall be designed in conjunction with anchor bolts to satisfy the condition of Equation 9-3.

9.4.1 Prestressed Concrete Beam End Diaphragms at Expansion Joints

Delete the third paragraph and replace with the following:

Closed cell extruded polystyrene foam shall be used to provide gaps between the shear keys and the concrete diaphragms. The foam shall provide ¼” to ½” gaps on the sides of the shear keys and 2” gaps between the bottoms of the concrete diaphragms and the tops of the shear keys. Details are provided in Figure 9.2 .This allows for the anchor bolts to be engaged in the shear force transfer between the superstructure and the substructure.

9.4.2 Prestressed Concrete Beam Closure Diaphragms

Delete and replace the section with the following:

Prestressed concrete beam closure diaphragms are used at interior bent locations to develop continuity for live loading between spans of a prestressed concrete beam superstructure. The bearings at the closure diaphragms are fixed. Shear keys may be used at the closure diaphragm locations when needed to provide transfer of seismic forces between superstructure and substructure. These shear keys shall be detailed as described in Section 9.4.1.

Figure 9.2 Concrete Superstructure Shear Key

Delete Figure 9.2 and replace with the following:

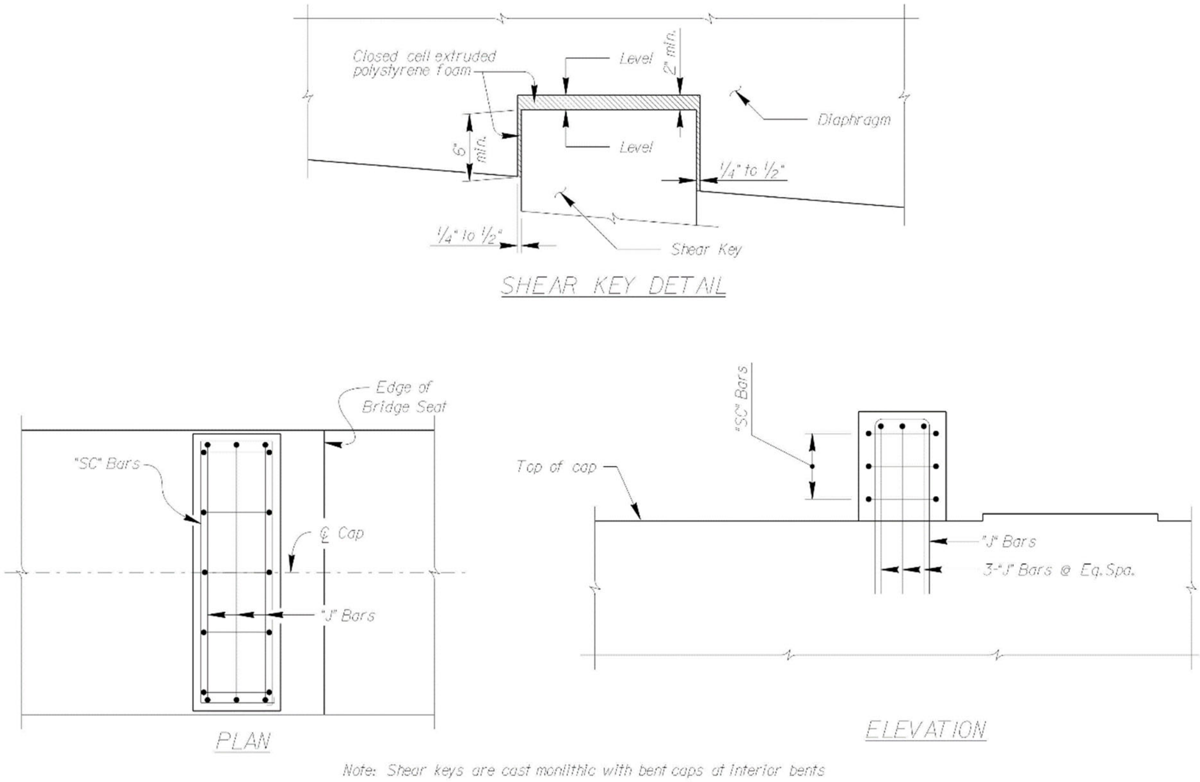


Figure 9.2 Concrete Superstructure Shear Key