Washington State Department of Transportation
Bridge and Structures Office

Design Memorandum

TO: All Design Section Staff
FROM: Bijan Khaleghi
DATE: January 17, 2013
SUBJECT: Lateral Confinement for Oversized Shafts for SDCs C and D

This design memorandum addresses the revised WSDOT requirement for minimum lateral confinement for single column-shafts foundation type for SDCs C and D. Other requirements of AASHTO SGS 8.8.12 and BDM 7.8.2-K remain applicable.

For single column-shaft connections, adequate confinement reinforcement must be included to resist the internal tension forces that develop at non-contact lap splice zones of column to shaft connections. Shaft lateral confinement reinforcement along the column embedment length shall satisfy Eq. 1:

$$\frac{A_{sh}}{s_{max}} \geq \frac{k f_{ul} A_l}{2\pi f_{ytr} l_s} \qquad (1)$$

where:

A_{sh} = area of shaft lateral confinement steel-one leg of spiral or welded hoop (in.^{2})

s_{max} = maximum spacing of shaft lateral confinement steel (in.)

k = efficiency factor, taken as 1 over the upper half of the column embedment length and 0.5 over the lower half.

f_{ul} = expected minimum tensile strength of column longitudinal reinforcement (ksi) 90 ksi for ASTM A615 and 80 ksi for ASTM A706

A_l= total area of column longitudinal reinforcement (in.^{2})

f_{ytr} = nominal strength of shaft lateral confinement steel (ksi)

l_s =standard splice length of required Class C splice for column longitudinal reinforcement (in.)

Additional lateral confinement reinforcement shall be provided in the upper half of the noncontact lap splice zone. The transverse reinforcement content shall be doubled for the upper half of the column embedment length. The additional lateral reinforcement in the upper half of the oversized pile shafts is required to control cracking in this region.

The above requirement may be waived if the steel casing is considered in the design capacity of the shaft in accordance with the October 7, 2012 Design Memorandum.

Background:

The confinement reinforcement requirements over the top portions of oversized pile shafts that connect with cast-in-place or precast columns are included to provide tie reinforcement to react prying forces introduced near the top of the shaft by the precast column. Experimental testing by Hung, et. al. 2012 has shown that adequate strength may be achieved in such connections, provided the lateral confinement reinforcement as defined by Eq.1 is included. The additional confinement reinforcement required over the upper half of the embedment length is intended to limit potential shaft damage, which tends to occur at the top of the shaft if adequate confinement is not provided.

The transverse steel content is a function of the column longitudinal steel; so the issue of the over strength design forces is covered. This steel could be viewed as minimum transverse reinforcing in the same way as the current BDM version for shaft splice-zone reinforcement is viewed. In a way, these recommendations can be viewed as refinements to the recommendations that David McLean made in his earlier work on this connection type.

This recommendation is only meant for use with column-to-oversized shaft connections and shall not be used for abutments or intermediate piers with multiple shafts per column.

The A_{sh}/s_{max} term gives the designer flexibility on spacing (depending) on the transverse bar size selected, but the maximum bar spacing limits still apply.

The reason for the heavier transverse steel near the top is to prevent the splitting that the UW researchers have seen at the very top of the shaft. Additionally, they have seen higher demands in the upper portion of the splice zone; so the k=1steel takes care of that increased demand.

If you have any questions regarding these issues, please contact Bijan Khaleghi at 360-705-7181 (khalegb@wsdot.wa.gov) .

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BDM Update:

Change the last paragraph of BDM Article 7.8.2-K as follows:

k = Factor representing the ratio of column tensile reinforcement to total column reinforcement at the nominal resistance. This ratio could be determined from the column moment-curvature analysis using computer programs Xtract or SAP 2000. To simplify this process, k=1.0 for the upper half, and k = 0.5 for the lower half of noncontact lap splice zone could safely be used in most applications.

Additional lateral confinement reinforcement shall be provided in the upper half of the noncontact lap splice zone. The additional lateral reinforcement in the upper half of the oversized pile shafts is required to control cracking in this region.