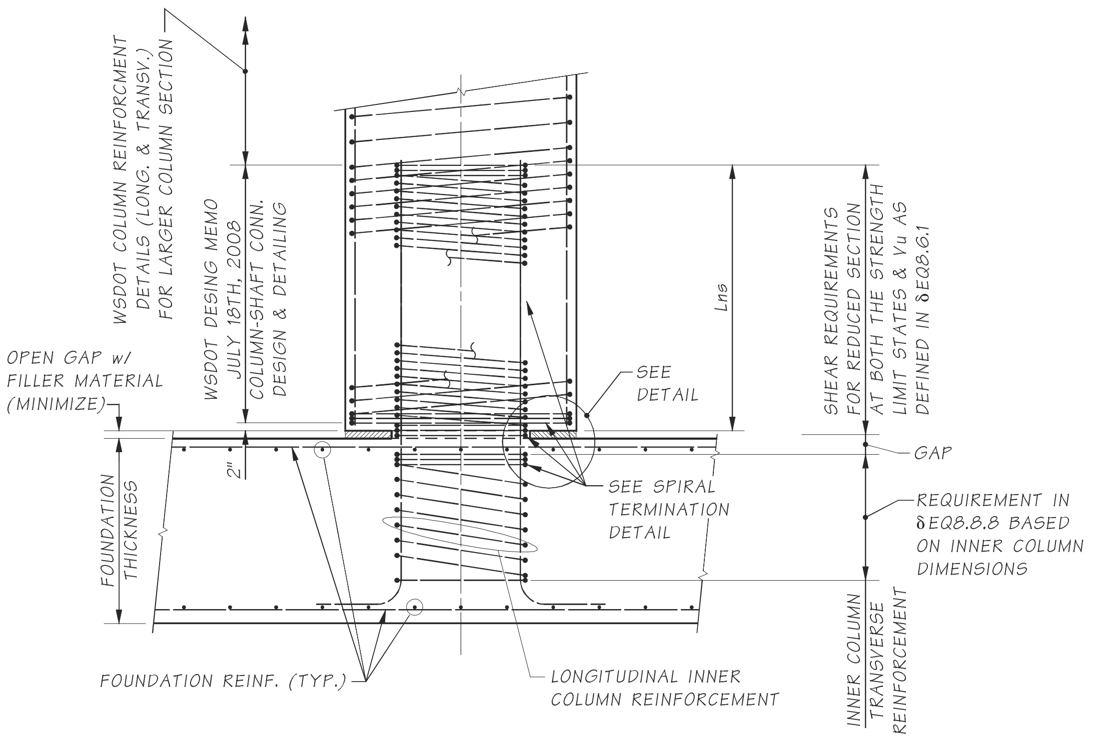
Washington State
Department of Transportation

Design Memorandum

TO: All Design Section Staff

FROM: Bijan Khaleghi
DATE: June 23, 2009
SUBJECT: Reduced Column Base Fixity

This memorandum establishes a consistent method for using a reduced column section, per the AASHTO Seismic Guide Specification, for using reduced column section to decrease overstrength plastic demands into the foundation. The conceptual detail for reduced column base fixity is shown below for a spread footing foundation. This concept could be used for shaft and pile supported foundations. Traditional column designs are preferred over this detail, but may be used if it is determined that traditional details will not satisfy the design code requirements due to architectural, balanced stiffness, or other project specific requirements.



TYPICAL SECTION FOR REDUCED FIXITY OF COLUMN AT FOUNDATION

1) INNER CONCRETE COLUMN

a) LONGITUDINAL REINFORCING

i) The longitudinal inner column reinforcement shall extend a distance of L_{ns} into the column and shall be set on top of bottom mat reinforcement of foundation with standard 90 degree hooks.

$L_{ns} = L_s + sc + L_{pa}$, where:

$L_s = 1.7^* L_{ac}$ (for Class C lap splice)
L_{ac} = development length of bar from the Seismic Guide Spec. 8.8.4.
sc = distance from longitudinal reinforcement of outer column to inner column.
L_{pa} = Analytical Plastic Hinge Length defined in the Seismic Guide Spec. 4.11.6-3.

ii) The longitudinal reinforcing in the inner column shall meet all the design checks in the AASHTO Seismic Guide Specification and AASHTO LRFD Bridge Design Specification. Some specific checks will be addressed as follows:

(1) A Shear Friction check shall be met using the larger of the plastic shear capacity of the inner column or the ultimate shear demand from strength load cases at the hinge location. The area of longitudinal inner column reinforcement, A_{st}, in excess of that required in the tensile zone for flexural resistance (usually taken as ½ the total longitudinal bars) may be used for the required shear friction reinforcement, A_{vf}.

(2) The flexural capacity of the inner column shall be designed to resist the Strength load cases and meet cracking criteria of the service load cases. Special consideration shall be given to construction staging load cases where the column stability depends on completion of portions of the superstructure.

(3) The axial capacity of the inner column shall meet the demands of Strength load cases, including case IV, assuming the outer concrete has cracked and spalled off. The gross area, A_g, shall be the area contained inside the spiral reinforcement.

(4) The inner core shall be designed and detailed to meet all applicable requirements of Section 8 of the Seismic Guide Specification.

b) TRANSVERSE REINFORCING

i) The upper portion of the transverse reinforcement, inside the larger column dimension, shall meet all the requirements of the AASHTO Seismic Guide Specification and AASHTO LRFD Bridge Design Specification. The demand shall be based on the larger of the overstrength plastic shear demand of the inner column or the ultimate shear demand from strength load cases at the hinge location. This upper portion shall be extended to the top of the longitudinal reinforcement for the inner column (L_{ns}).

ii) The lower portion of transverse reinforcement, in the foundation, shall meet the minimum requirements of the AASHTO Seismic Guide Specification 8.8.8, for compression members, based on the dimensions of the inner column. This reinforcement shall be extended to the bend radius of the of the longitudinal inner column reinforcement.

iii) A gap in the inner column transverse reinforcement shall be sized to allow the foundation top mat reinforcement and foundation concrete to be placed prior to setting the upper portion of the transverse inner column reinforcement. This gap shall be limited to 5 inches; a larger gap will require the Bridge Engineer's Approval. The spiral reinforcement above the footing shall be placed within 1 inch of the top of footing to reduce the required gap size. The WSDOT Spiral termination details will be required at each end of this gap, the top of the upper transverse reinforcement, but no the bottom of the lower transverse reinforcement.

c) Analytical Plastic Hinge Region

i) The analytical plastic hinge length of the reduced column section shall be based on horizontally isolated flared reinforced concrete columns, using equation 4.11.6-3 of the AASHTO Seismic Guide Specifications.

ii) The end of the column which does not have a reduced column section shall be based on equation 4.11.6-1 of the AASHTO Seismic Guide Specifications.

2) OUTER CONCRETE COLUMN

a) The WSDOT Bridge & Structures Office normal practices and procedures shall be met for the column design, with the following exceptions:

i) The end with the reduced column shall be detailed to meet the seismic requirements of a plastic hinge region. This will ensure that if a plastic hinge mechanism is transferred into the large column shape, it will be detailed to develop such hinge. The plastic shear this section shall be required to resist shall be the same as that of the inner column section.

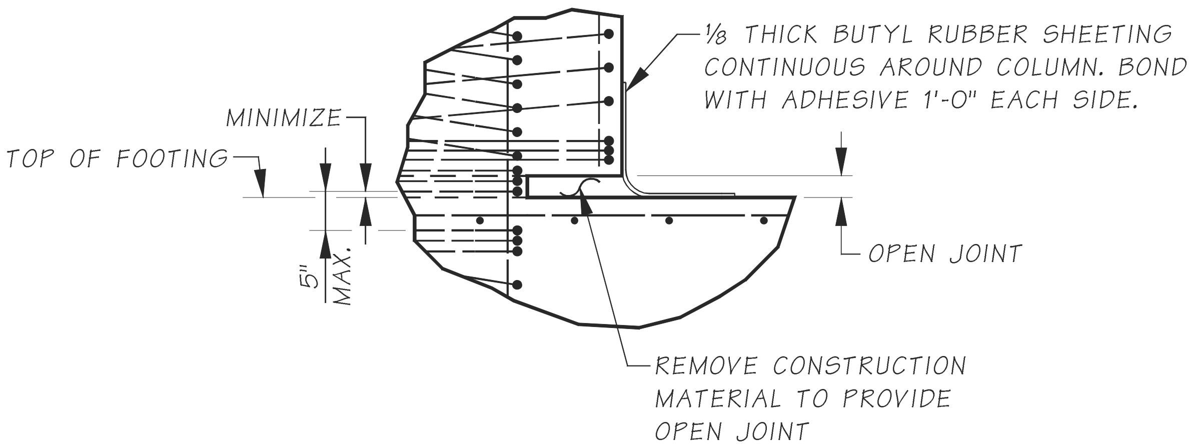
ii) The WSDOT spiral termination detail shall be placed in the large column at the reduced section end, in addition to other required locations.

iii) In addition to the plastic hinge region requirements at the reduce column end, the outer column spiral reinforcement shall meet the requirements of the WSDOT Design Memo dated July, 18th, 2008. The k factor described in this memo shall be taken as 0.5 if the column axial load, after moment distribution, is greater than $0.10f'_cA_g$ and taken as zero if the column axial load is in tension. A_g shall be taken as the larger column section. Linear Interpolation may be used between these two values.

b) This procedure described the requirements when the reduced column section was placed at the foundation. Similar checks will be required if the reduced section were placed at the crossbeam, along with any additional checks required for those sections. One such additional check is joint shear in the crossbeam based on the overstrength plastic capacity of the reduced column section.

c) The column end without the reduced column section shall be designed with WSDOT practices for a traditional column, but can account for the reduced overstrength plastic shear, applied over the length of the column, from the overstrength plastic capacities at each column end.

3) GAP IN CONCRETE AT REDUCED COLUMN SECTION



OPEN GAP DETAIL

EXAMPLE

a) This gap shall be minimized, but not less than 2 inches. The gap shall be constructed with a material sufficient strong to support the wet concrete condition. The final material must meet the requirements described below. If a material can meet both conditions, then it can be left in place after construction, otherwise the construction material must be removed and either cover the gap or fill the gap with a material that meets the following:

   i) The material in the gap must keep soil or debris out of the gap for the life of the structure. This is more specific if the gap is to be buried under fill at the foundation and inspections will be difficult / impossible.

   ii) The gap shall be sized to accommodate rotations from service, strength and extreme load cases. In no loading condition shall the edge of the larger column section cause a compressive load on the footing. If a filler material is used in this gap which can transfer compressive forces once it has compressed a certain distance, then the gap shall be increased to account for this compressive distance of the filler material.

Background

The AASHTO Guide specifications for LRFD Bridge Seismic Design results in some cases in higher force demand for foundation design. This memorandum gives clearer guidelines on how to use reduced fixity in a column to decrease overstrength plastic demands into the foundation.

If you have any questions regarding these issues, please contact Stuart Bennion at 705-7168 or Bijan Khaleghi at 705-7181.

cc: Mohammad Sheikhizadeh, Bridge Construction - 47354

F. Posner, Bridge and Structures – 47340