Washington State Department of Transportation
Bridge and Structures Office

Design Memorandum

TO: All Design Section Staff
FROM: Bijan Khaleghi
DATE: October 3, 2016
SUBJECT: Hinge Diaphragms at Interior Piers

This design memorandum allows the use of concrete hinge diaphragms at interior continuous piers in new bridges. The hinge provides reduced stiffness at the interior pier about the axis parallel to the crossbeam, thus reducing the design loads enough to eliminate plastic hinges at the top of the columns, in that direction. Application of this type of connection is beneficial at piers that have short columns where the plastic overstrength demand is large. By reducing the connection stiffness at the hinge, the upper hinge is eliminated and the effective column length is increased for the lower hinge, reducing the overstrength shear demand.

The axial dead load combined with confinement reinforcing around the throat of the hinge help to minimize the degradation of the hinge under large rotations. The throat width must be sized to resist the bearing forces, but also minimized to limit the distortion under those rotations. The throat gap must also be checked to accommodate 1.5 times the design rotations, but limited to 0.75 in. maximum. Large rotations may be mitigated by allowing the bottom of the diaphragm to taper at a maximum 5 degree angle. Additionally, the hinge shear key must be designed to resist the lateral shear demand based on AASHTO LRFD requirements for interface shear. Conservatively, the concrete shear friction and axial load are ignored and the dowel size and spacing are designed to resist the lateral demand.

The construction joint used to secure the girder bottom flanges is limited to 1'-3" above the top of crossbeam to fix the girder bottom flange. This allows flexibility at the girder ends during deck placements, while providing stability. Larger fixed depths at the girder ends have been observed to split the diaphragm along the dowel plane as the deck concrete is placed.

The hinge is assumed to be pinned when determining the bridge deformations, including pier displacements and rotations. However, some stiffness must be assumed when determining the column overstrength shear demand. This may affect the column shear reinforcing design and hinge ductility.

Transverse stiffness of the pier is not reduced due to the hinge and the design loads are resisted by the crossbeam section only. The diaphragm is not included on the section capacity. Plastic hinges may form at the top of multi-column bents in the transverse direction.

Background:
In the past concrete hinge diaphragms were only used in low seismic areas such as east of the Cascade Mountains. It was limited to use in widening of existing bridges with hinge diaphragms and was excluded from use in new structures. It was assumed that the seismic rotations would compromise the hinge performance, causing the dowels to buckle under lateral loads.

Research has shown that with proper design and detailing, concrete hinges can accommodate large rotation without signs of failure. Therefore use of concrete hinges can be considered in higher seismic areas. Integral crossbeams are still the preferred details, but in situations where reducing the lateral demand in necessary, concrete hinges may be considered.

BDM section 7.3.6 discusses column hinges and their use "above a crossbeams or pier wall". This statement caused confusion in the application of diaphragm hinges and will be removed.

If you have any questions regarding this policy memorandum, please contact Michael.Rosa@wsdot.wa.gov at 360-705-7156 or Bijan.Khaleghi@wsdot.wa.gov at 360-705-7181 or.

cc: Mark Gaines, Construction Office – 47354
Craig Boone, Bridge and Structures – 47340

Bridge Design Manual Revisions:

Section 5.6.2 E.3 End Type C shall be revised as follows:

> End Type C as shown in Figure 5.6.2-5 is for continuous spans and an intermediate hinge diaphragm at an intermediate pier. There is no bearing recess and the girder is temporarily supported on oak blocks. ~~In the past, this detail was used in low seismic areas such as east of the Cascade Mountains. This end type shall not be used on new structures and is restricted to the widening of existing bridges with hinge diaphragms at intermediate piers.~~ This detail may be used to reduce the seismic demand at an intermediate pier by allowing rotation about the axis parallel to the crossbeam. The reduced pier stiffness will lower the plastic overstrength shear demand (Vpo), allow for shorter columns and eliminate the plastic hinge at the top of each column. While the diaphragm hinge is intended to act as a pin, there may be some residual stiffness at the connection that shall be determined by the designer.

This stiffness will move the point of inflection down the pier, inducing some plastic overstrength shear demand.

The hinge connection should be assumed pinned to determine the pier displacement and ductility demand for seismic analysis.

The designer shall check the edge distance and provide a dimension that prevents edge failure, or spalling, at the top corner of the supporting cross beam for load from the oak block including dead loads from girder, deck slab, and construction loads.

For prestressed concrete girders with intermediate hinge diaphragms, designers shall:

a. Check size and minimum embedment in crossbeam and diaphragm for hinge bars. Bars shall be sized based on interface shear due to calculated plastic overstrength shear force (Vpo) from the column while ignoring the concrete cohesion and axial load contributions.

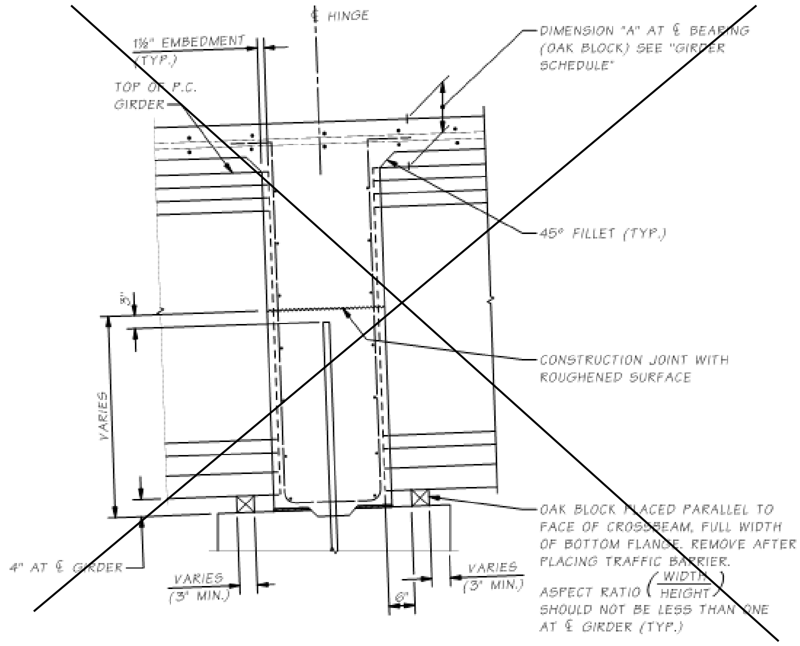
b. Design the width of the shear key to take the factored vertical bearing force per AASHTO LRFD 5.7.5 at the Strength limit state. The maximum shear key width shall be limited to 0.3d, where d is the width of the diaphragm.

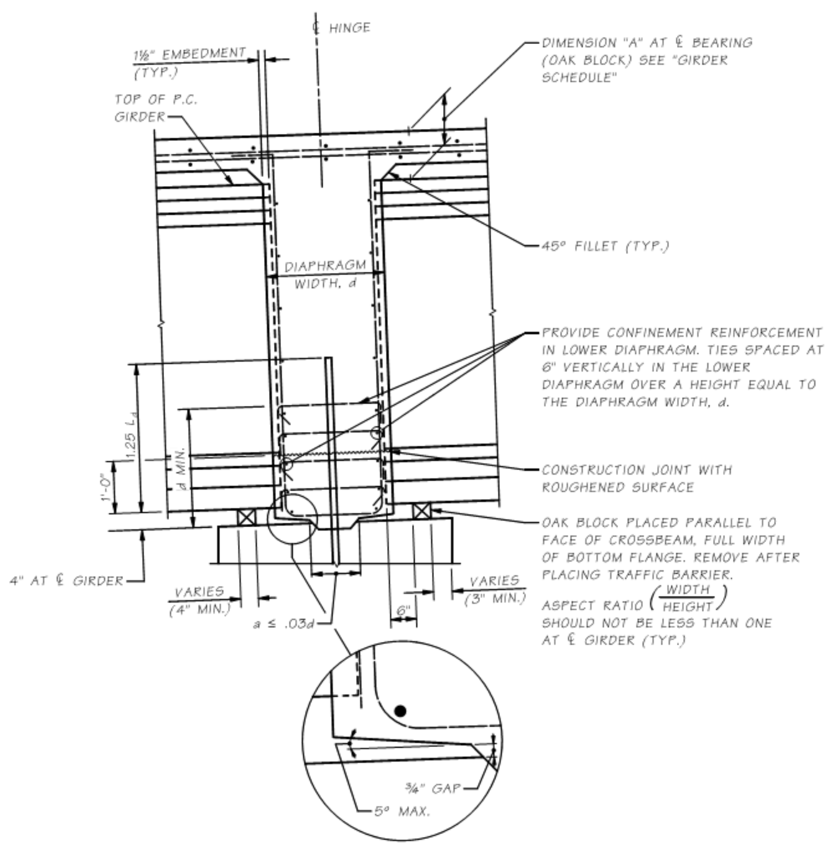
c. Confinement reinforcement shall be added to the diaphragm between the girders over a vertical distance equal to or greater than the diaphragm width. Confinement shall be no less than #4 ties bars spaced at 12 in. longitudinally and staggered 6 in. vertically.

d. The throat of the hinge gap shall be no larger than 0.75 in. The bottom of diaphragm may taper up to 5 degrees maximum to allow for 1.5 times the elastic service, strength or extreme rotation. The material used to form the gap shall be strong enough to support the wet concrete condition and shall be removed after concrete placement.

e. Check interface shear friction at girder end (see Section 5.2.2.C.2).

Design of the pier in the transverse direction (parallel to the crossbeam axis) shall be performed per the AASHTO Seismic Guide Specifications.





End Type C (Intermediate Hinge Diaphragm)
Figure 5.6.2-5

Section 7.3.6 Column Hinges first paragraph shall be revised as follows:

Column hinges of the type shown in Figure 7.3.6-1 were built on past WSDOT bridges. ~~Typically they were used above a crossbeam or wall pier.~~ These types of hinges are suitable when widening an existing bridge crossbeam or wall pier with this type of detail. The area of the hinge bars in square inches is as follows: