Washington State Department of Transportation
Bridge and Structures Office

DESIGN MEMORANDUM

TO: All Design Staff
FROM: Bijan Khaleghi
DATE: July 4, 2012
SUBJECT: Extended Strands Continuity Design Criteria

This design memorandum defines WSDOT policy for the use of extended strands and crossbeam ties at intermediate piers of prestressed girder bridges. WSDOT BDM Article 5.1.3D-3 defines the requirement for the number of extended bottom prestressing strands at intermediate piers to resist loads from creep effects, shrinkage effects, and positive seismic moments.

Continuity of extended strands is essential for all prestressed girders bridges with fixed diaphragms at intermediate piers. Strand continuity may be achieved by directly overlapping extended strands as shown in Figure 1, by use of strand ties as shown in Figure 2, by the use of the crossbeam ties as shown in Figure 3 along with strand ties, or by a combination of all three methods. The following methods in order of hierarchy shall be used for all precast girders for creating continuity of extended strands:

Method 1: Direct extended strands overlapping shall be used at intermediate piers without any angle point due to horizontal curvature and for any crossbeam width. This is the preferred method of achieving extended strand continuity. Congestion of reinforcement and girder setting constructability shall be considered when large numbers of extended strands are required. In these cases, strand ties may be used in conjunction with extended strands.

Method 2: Strand ties shall be used at intermediate piers with a girder angle point due to horizontal curvature where extended strands are not parallel and would cross during girder placement. Crossbeam widths shall be greater than or equal to 6 ft measured along the skew. It is preferable that strand ties be used for all extended strands, however if the region becomes too congested for rebar placement and concrete consolidation, additional forces may be carried by crossbeam ties up to a maximum limit as specified in equation (1) below.

Method 3: For crossbeams with widths less than 6’ and a girder angle point due to horizontal curvature, strand ties shall be used if a minimum of 8” of lap can be provided between the extended strand and strand tie. In this case the strand ties shall be considered fully effective. For cases where less than 8” of lap is provided, the

effectiveness of the strand tie shall be reduced proportional to the reduction in lap. All additional forces not taken by strand ties must be carried by crossbeam ties up to the maximum limit as specified in equation (1) below. If this limit is exceeded, the geometry of the width of the crossbeam shall be increased to provide sufficient lap for the strand ties.

The area of transverse ties considered effective for strand ties development in lower crossbeam shall not exceed:

$$A_s = \frac{1}{2}\frac{A_{ps} f_{py} n_s}{f_{ye}} \qquad (1)$$

Where:

A_{ps} Area of strand ties, in^2

n_s Number of extended strands that are spliced with strand and crossbeam ties

f_{py} Yield strength of extended strands, ksi

f_{ye} Expected yield strength of reinforcement, ksi

Two-thirds of A_s shall be placed directly below the girder and the remaining of A_s shall be placed outside the bottom flange width as shown in Figure 3.

The size of strand ties shall be the same as the extended strands, and shall be placed at the same level and proximity of the extended strands.

Background

Extended strands at intermediate crossbeams are used to connect the ends of girders with diaphragms and resist loads from creep effects, shrinkage effects, and seismic positive moments. These strands are to be developed within the diaphragm between the two girder ends at intermediate piers. The objective of extending the strands is to ensure that the tensile force carried by the strand can be transferred to the opposite side of the diaphragm, thus ensuring an adequate tensile load path for joint forces. Extended strand that overlaps with strand from the opposite girder or use of strand ties facilitate development of strands within the diaphragm between two girder ends. It is preferable that extended strands, as shown in Figure 1, be used to the maximum extent possible. This arrangement provides the stiffest and most direct tensile load path. However for constructability, strand ties may be utilized to provide extension of the strands into the diaphragm, as shown in Figure 2. The extension is provided by a lap splice between the strand ties and the extended tensile strands. Additionally, the top of the ties in the lower crossbeam may be considered to contribute to the extension of the strand tensile force into the diaphragm, as shown in Figure 3. This force transfer takes place through non-contact lap-splice (strut and tie) action between the extended strands and the lower crossbeam ties.

Because the strand strength is much higher than that of deformed bars, strand ties are recommended. The number and the size of the strand ties shall be the same as that of the extended strands that are being developed with strand ties. Circular strand anchors of 2¾”ø x 1”should be installed at 4” from the opposite girder end. Circular strand anchors are required for ease of construction. The strand extension beyond the face of strand anchors shall be limited to 1”.

The top of lower crossbeam is affected when extended strands are developed by a compressive strut forming between the strand anchors and crossbeam ties. The designer shall calculate the number of crossbeam ties as shown in Equation 1, which assumes that one half of the non-overlapping strand force is transferred from the strand anchors to the lower crossbeam ties through strut action. It is also assumed that only two-thirds of the lower crossbeam ties need to be placed directly below the girders within the width of bottom flange since the affected zone on crossbeam ties is larger than the width of bottom flange. The tie bar size may be increased to meet the design requirement but the spacing should preferably kept the same as the crossbeam stirrup spacing for ease of construction. Ties may be bundled, if necessary. The tie bar size shall not be less than the crossbeam stirrups bar size.

If you have any questions regarding these issues, please contact Geoff Swett at 705-7157 (swettG@wsdot.wa.gov) or Bijan Khaleghi at 705-7181(KhalegB@wsdot.wa.gov)

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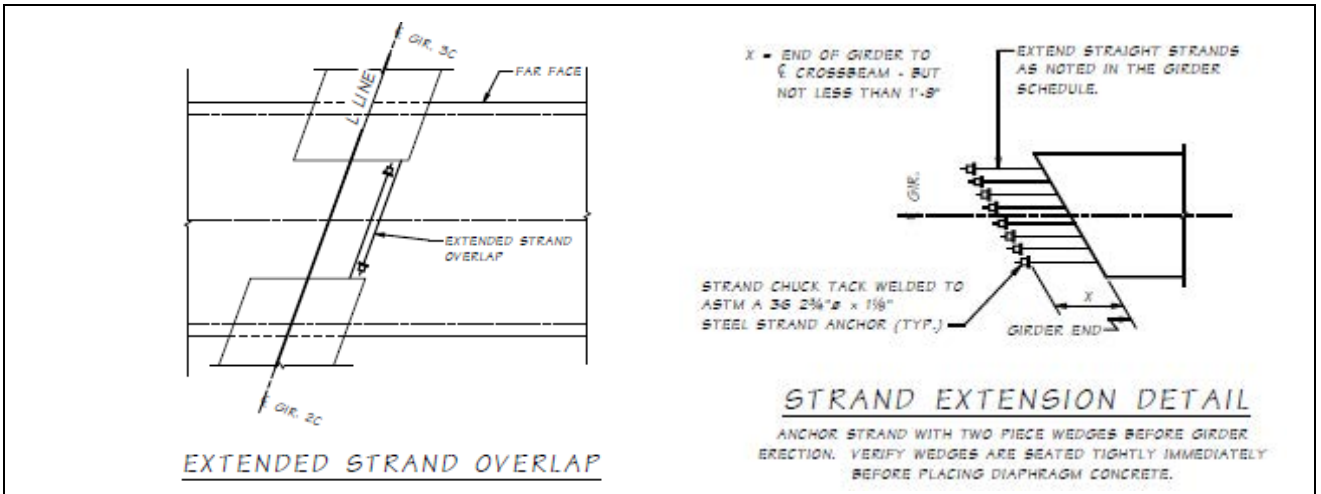
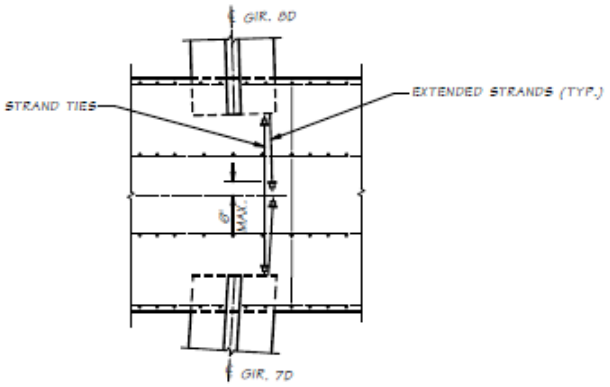
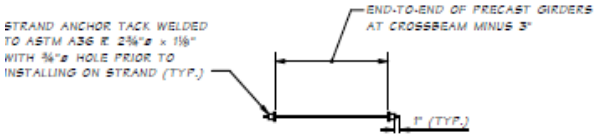


Figure 1: Overlapping Extended Strand

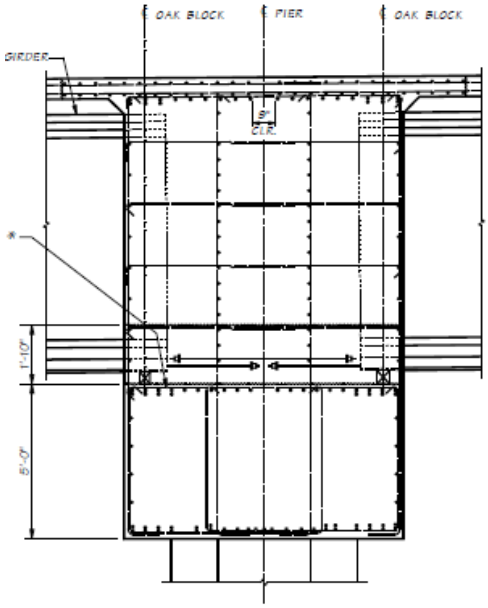


STRAND TIE DETAIL

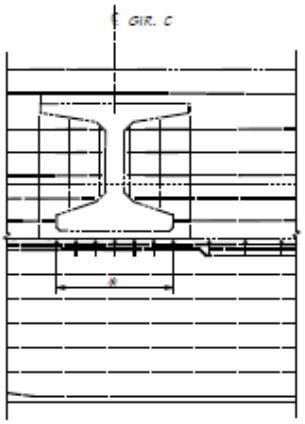


STRAND TIE DETAIL

Figure 2: Strand Ties



INTEGRAL DIAPHRAGM DETAIL



CROSSBEAM TIE DETAIL

Figure 3: Lower Crossbeam Ties