Oregon Department of Transportation

SECTION 1.11
Substructures

Revisions for the current edition are highlighted yellow. Deleted text is not marked.

Past editions of the Bridge Design Manual are available through our website.

1.11.1 Retaining Structures, General

1.11.2 End Bents

1.11.3 Interior Bents

1.11 Substructures

1.11.1 Retaining Structures, General

See *BDM 1.12.5* for Retaining Structures.

1.11.2 End Bents

1.11.2.1 General

Where end bents or retaining walls are located adjacent to roadway construction, locate the top of footings at or below the elevation of the bottom of the roadway subgrade. Locate the top of the footing a minimum of 1 foot below the surface of the ground. The effect of items such as utilities (see *BDM 1.12.6*), ditches and future widening should also be considered.

1.11.2.2 Terminology

In this section and elsewhere in the *BDM*, the terms **end bent** and **abutment** are used interchangeably. **Integral Abutment** is the industry standard term used to describe abutments that provide a continuous connection between the superstructure and the substructure. However, for consistency on ODOT bridge drawings, all bridge support locations are referred to as **bents**. Refer to the glossary in the *Appendix* for definitions of the terms **Abutment**, **Bent** and **Pier**. A possible exception could include the rehabilitation of an existing bridge, where the original plans called out **abutments** or **piers**, etc. and it would be less confusing to keep the same terminology as the existing plans.

1.11.2.3 Design

Lateral earth pressures at the end bent must be well thought out by both the bridge engineer and the geotechnical engineer. To more consistently model the behavior of the bridge and to ensure the design loads are constructed a detail has been developed for use in the plan set. The bridge engineer is responsible for including the completed detail, and pay limit diagram. The load diagram and associated notes in the plan set

C1.11.2.3

Historically a one foot neat-line with drain material has been used as a detail. This detail allows for easy calculation of the excavation and drain material quantities. However, the detail does not provide limits for the backfill at the end bents and wingwalls and while the specifications require granular structure backfill there is not consistent direction for the extent of the backfill. Thus, there are no assurances that the designed lateral earth

will be provided by the geotechnical engineer.

Provide access for inspection of bearings, shear lugs and backwalls for semi-integral abutments and access inspection for backwalls of integral abutment per *BDM 1.15.5*.

pressures are achieved in construction which will also limit deformation.

When Earthquake Restraining Systems and Earthquake Resisting Elements are used for passive restraint the engineering soil parameters and construction become more critical for the operational performance of the bridge. Increases in height to mobilize the passive soil pressure for seismic resistance may be necessary to achieve sufficient resistance.

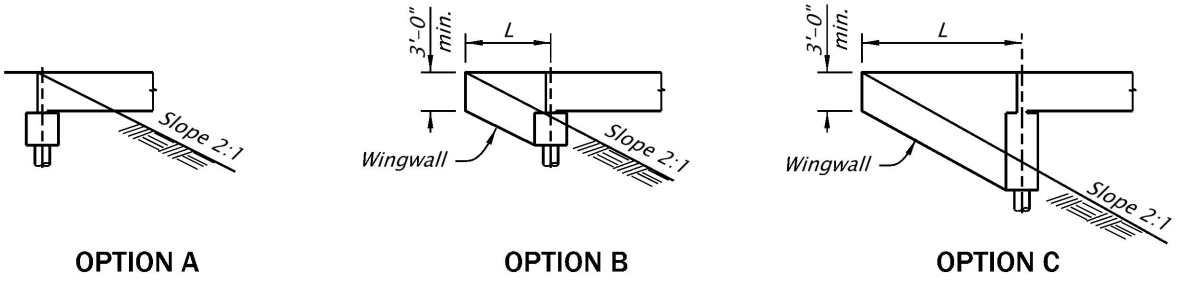
1.11.2.1 Determining Bridge Length

Options for the end bent in relation to the end fill intersection with the finish grade are shown in *Figure 1.11.2.1-1* and include:

- Option A, no wingwalls, but a longer structure than for options B and C.
- Option B, the structure length is shorter, but short wingwalls to retain the fill.

Option C, the structure length is shorter yet, but longer wingwalls and a taller abutment wall to retain the fill.

Figure 1.11.2.1-1 End Bent Location Options



OPTION A OPTION B OPTION C

C1.11.2.1

Generally, option B will provide the least cost, especially for prestressed slab spans. For option C, larger longitudinal forces from lateral soil loads must be resisted by the superstructure and substructure.

1.11.2.1.1 Slope Paving and Railroad Slope Protection

Where required, provide slope paving on the bridge end fill according to Bridge Standard Drawing *BR115*.

For a highway bridge crossing over a railroad, consult with the railroad to determine required slope protection.

C1.11.2.1.2

Slope paving is generally required where a roadway passes under a bridge. Also consider slope paving where a bridge crosses over a sidewalk or park.

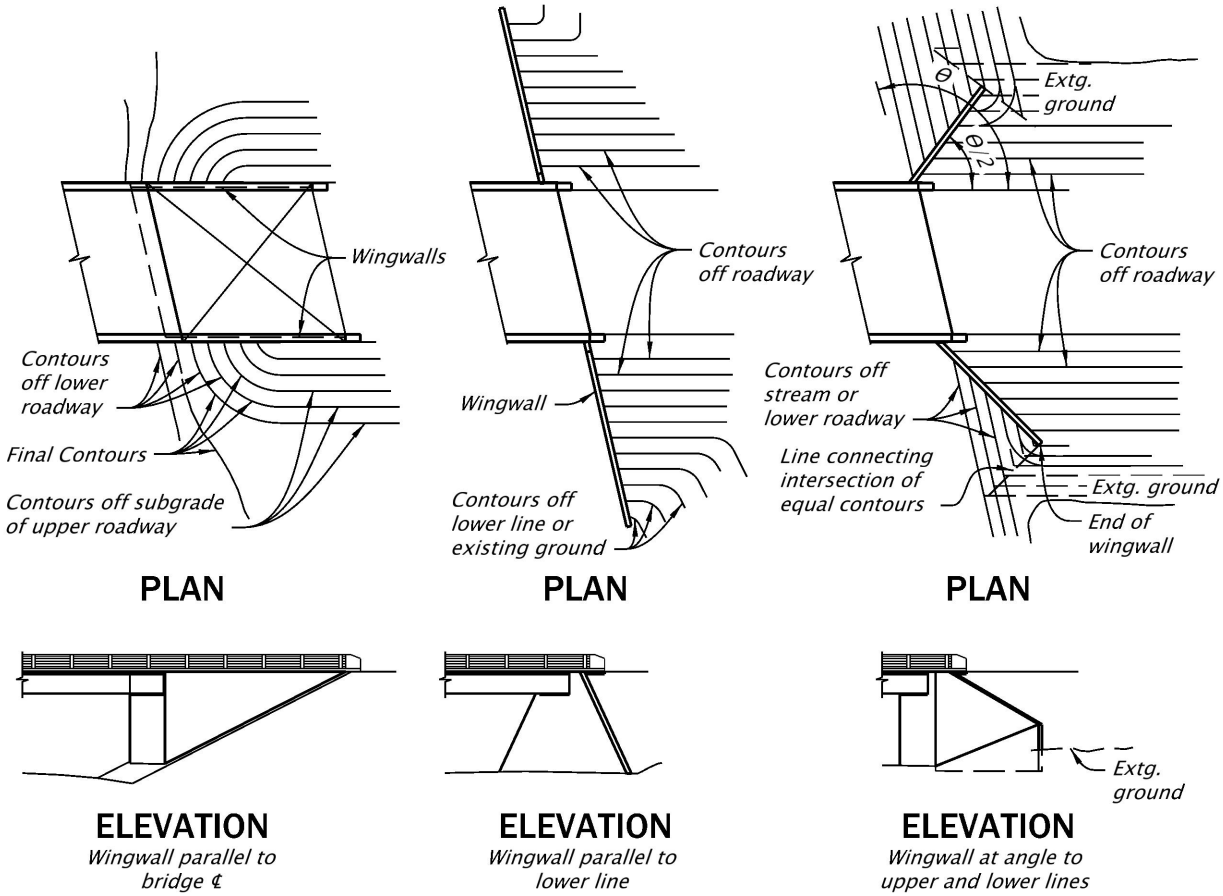
Rock slope protection may be required on the end fill slope of railroad undercrossings.

1.11.2.2 Wingwall Location

Locate wingwalls for end bents as follows:

- Walls parallel to the structure are used for filled or **false** (unfilled) bents. These are generally used for grade separation structures where the face of the bent is quite a distance back from the toe of the slope under the structure.
- Walls parallel to bridge bents are generally avoided due to safety or stream flow considerations.
- Walls at an angle to both structure and lower roadway or stream. The angle is generally half the angle between the structure and the lower roadway or stream center lines, as this usually leads to a minimum length wall. The end of the wall is determined by plotting final contours off the upper and lower profile lines. The point where the contours of equal elevation intersect determines the location of the end of the wall.

Figure 1.11.2.2-1 Wingwalls at End Bents



1.11.2.3 Wingwall Design and Construction

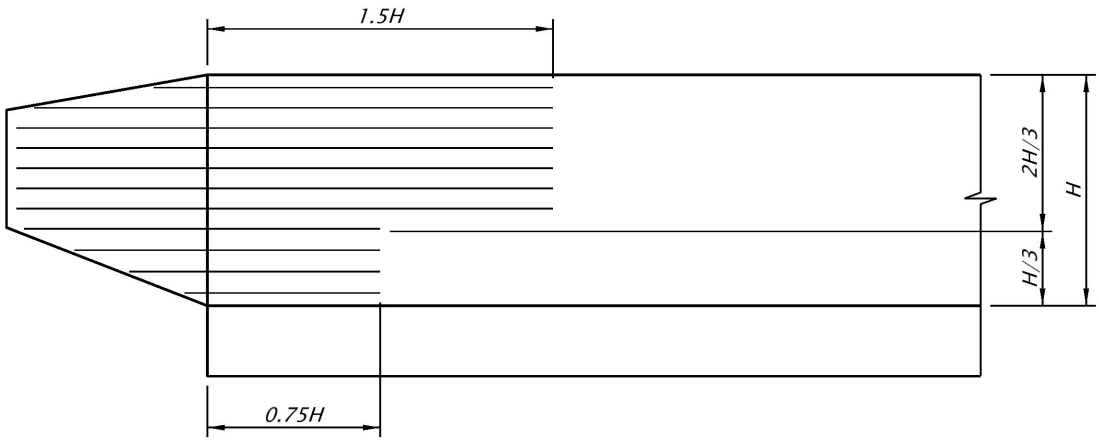
DESIGN

For cantilever wingwalls on abutments with relatively stiff footings (footing width is at least three times abutment wall thickness), the horizontal reinforcement in the fill face of the abutment wall resisting the moment caused by earth pressure on the wingwall need not extend farther from the wingwall-abutment juncture than the following:

- 1.5H for the top 2/3 of the abutment wall height.
- 0.75H for the bottom 1/3 of the abutment wall height.

Where abutment walls with wingwalls are designed with thickened tops for bearing seats or backwalls, those thickened portions should be designed to carry 1/2 to 2/3 of the bending moment in the upper half of the abutment wall. Reinforcing between the abutment wall and the wingwall should extend beyond the juncture enough to develop the strength of the bar reinforcement.

Figure 1.11.2.3-1 Wingwall Reinforcement



CONSTRUCTION

Consider all stages of construction when wingwalls are cantilevered from an abutment or pilecap. When the abutment or pilecap would be unstable or overstressed under the dead load of the wingwalls before the superstructure or backfill are placed, the **Bent Construction Sequence** on the plans should require that the concrete in the wingwalls not be placed until the superstructure or backfill are in place. Do not count on there being soil under the wingwall unless the wall has its own footing.

The height of the wingwall at the outer end of the wall should be a minimum of 3 feet. The slope of the bottom of the wall should be a maximum of 2:1.

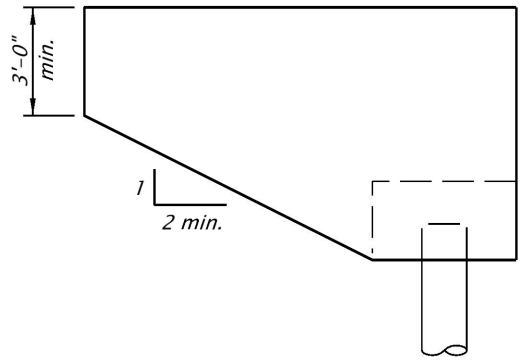
The *Special Provisions* and detail drawings should require that the embankment fill be placed to the elevation of the bottom of the wall before the wingwalls are constructed. In other words, bridge end bent wingwalls shall be cast against undisturbed material or well compacted backfill. The designer may want to use some discretion in this matter. A 24 foot wall would normally always need to be constructed on compacted fill, while a 6 foot wall could be constructed and backfilled at later time.

For walls shorter than about 8 feet, the bottom of the wall can be formed level, at the discretion of the designer or at the contractor's option. This adds some cost in materials, which may be offset by cost savings from easier construction. Potential benefits:

- Wingwalls are founded on level ground, no sloped or elevated bottom forms are required.
- Adds stability to abutment.
- Helps contain approach embankment at stream crossings when primary scour protection fails.

Due to concerns about stability and the potential for migrating of fresh concrete over the top of wingwall forms, the slope of the top of a wingwall should not exceed the maximum slope of the adjacent embankment nor 1.5:1 without a special stability investigation.

Figure 1.11.2.3-2 Wingwall Slopes



1.11.2.4 Bents on MSE Walls

Refer to the *ODOT Geotechnical Design Manual, Chapter 15* for the design of MSE Walls. Provide a concrete facing for all MSE abutment walls and wingwalls.

1.11.2.5 Integral Abutments

Use integral abutments wherever site conditions and structure geometry are suitable for such structures and the conditions and criteria described in this section are met. In integral abutments, expansion joints and bearings are eliminated and the superstructure is fully integral with the abutment. This results in numerous potential benefits including:

- Greater structure redundancy.
- Simplified construction.
- Reduced construction cost and time.
- Reduced maintenance cost.
- Stiffer longitudinal response at abutments.

For a continuous bridge with expansion end bent connections, the interior bents take all of the longitudinal and transverse force effects. By using integral abutments in place of the expansion end bent connections, some of the longitudinal and transverse forces are distributed into the integral abutment (piles and backfill soils), thereby reducing the net forces on the interior bents. Integral abutments can reduce the longitudinal and transverse force effect considerably in a continuous bridge as compared to a bridge with expansion joints at the abutments.

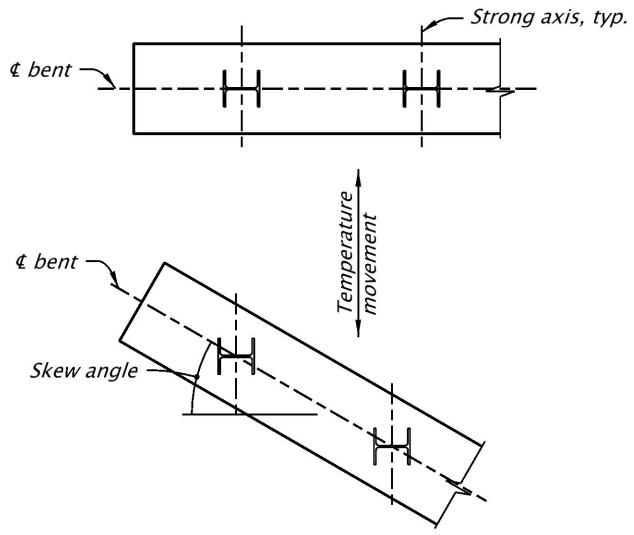
Use integral abutments under the following conditions:

- When the end bent is founded on steel pipe piles or H-piles. Do not place integral abutment foundations on top of, or through, MSE retaining wall reinforced backfill. For all other foundation types, see guidelines for semi-integral abutments.
- When bed rock is a minimum of 12 feet from the bottom of the pile cap. Avoid using pre bored piles when bed rock is close to the surface, since this type of construction has been uneconomical.
- When there is negligible potential of abutment settlement which does not affect the serviceability of the bridge.
- When the radius of horizontal curvature is greater than 1200 feet.
- When the skew angle is less than 30 degrees.
- When, for all service limit states, movement at the top of integral abutment piles does not exceed ±1.5 inches from the undeflected position. The corresponding range of pile movement is therefore 3 inches when the superstructure is made integral with the piles at the mean annual temperature.

Design Guidelines for Integral Abutments:

- Use a U-shaped abutment (wingwalls parallel to roadway alignment) when possible.
- Use H-pile with strong axis in the direction of temperature movement. See *Figure 1.11.2.5-1.*

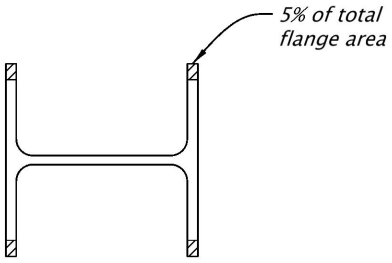
Figure 1.11.2.5-1 H-Pile Orientation



- Embed piles into the pile cap to develop moment fixity. See *BDM 1.10.5.4(1)* Piling Details.
- Preboring may be necessary in some cases where pile design stresses are excessive due to thermal movements and cannot be accommodated without special foundation design and construction. The cost of preboring for the piles should be compared to the benefits gained by using an integral abutment design. Increasing the number of piles or the use of larger piles in the abutment may decrease individual pile stresses to acceptable limits. When preboring is required, and cost effective, then consider preboring an oversized hole. The prebore dimensions should be at least 4 inches or more in diameter larger than the diagonal dimension of the pile and large enough to accommodate the estimated pile deflection. Backfill the area around the pile with loose sand conforming to the current *SP 00360.10* or as recommended by the geotechnical designer. Do not compact the sand backfill material. Bentonite or pea gravel backfill are not recommended since they may not provide for the long term flexibility required of the pile and soil system. The depth of prebore should be 10 feet or more or as required to provide the required pile flexibility to decrease pile stresses to an acceptable limit.
- Detail piles of integral abutments to resist uplift force from temperature differential between top and bottom of the pilecap. Refer to *Figure 1.10.5.4-6* for pile anchorage details.
- The design of integral abutment bridges with a grade change between abutments should consider both vertical and horizontal components of bridge longitudinal loads such as uniform temperature changes, creep, shrinkage, braking, seismic, and lateral earth pressure, on the resulting axial and flexural stresses in the piles.
- Develop a LPILE model using the full pile for soil and pile interaction. Evaluate pile deflections, bending moments and stresses using LPile computer program analysis.

- At the service limit state, H-pile flange yielding at each flange tip should not exceed five percent of the total flange area. See *Figure 1.11.2.5-2*. For steel pipe piles no yielding of section is permitted.

Figure 1.11.2.5-2 H-Pile Flange Yielding



- Consider the relative stiffness of the superstructure, substructure and any asymmetric span lengths in calculating end bent movement. Consider the potential for unequal thermal movements at end bents (integral abutments) due to asymmetric span lengths or changes in substructure stiffness.
- Consider torsion in components connected to integral abutments.
- Consider the combination of worst case events (except seismic) with temperature rise and fall.
- Specify placement and compaction requirements and an increased frequency of field density test requirements of the backfill material (minimum of two tests per stage of construction at each end bent) to achieve consistent soil stiffness behind both end bents.
- Consider the friction force between the bottom of the approach slab and structure back fill (expansion and contraction) in the superstructure design at the service limit state. Assume a friction coefficient of 0.54 unless specific measures are taken to reduce friction.
- Connect superstructure and end bents with a closure pour. Require a minimum of three days wait period between concrete deck placement and closure pour to release shrinkage stress in bridges with steel superstructures and include long term creep in your design for concrete superstructures. Include a note which requires backfill behind the abutment after closure pour.
- Where the range of abutment movement is less than ½ inch, the approach slab may be fixed to the superstructure and thermal movements accounted for by providing a saw cut in the approach pavement at the end of the approach slab. Where the range of abutment movement is ½ inch or more, provide an expansion joint between the approach slab and the deck so the approach slab is not dragged back and forth with thermal expansion and contraction. See *BDM 1.9.2.4.2* for additional information.
- In integral abutment bridge staged construction, a continuous abutment is capable of transferring traffic live load vibrations in one stage to the girders and the deck that are under construction in another stage. These vibrations can damage fresh concrete in the

deck. To minimize these vibrations, provide an expansion joint or closure segment in the integral abutment located between the stages of construction. See *BDM 1.9.1.3* for more discussion on vibrations.

- Specify deck casting sequences and deck closure pours at integral abutment connections and specify the range of temperature when the contractor may place the concrete on the plans and in the special provisions. Keep the range of temperature in the closure pour to not adversely affect the pile stress during temperature fall or rise.
- See design example in the following publication of the American Iron and Steel Institute *HIGHWAY STRUCTURES DESIGN HANDBOOK, Vol. II Chapter 5, Integral Abutments For Steel Bridges*, prepared for the National Steel Bridge Alliance by Tennessee DOT.

1.11.2.6 Semi-Integral Abutments

Recommendations for integral abutments also apply to semi-integral abutments, except as noted in this subsection.

Consider the use of semi-integral abutments, rather than integral abutments, on foundations that are stiff in the longitudinal direction, such as spread footings, drilled shafts, and concrete piles. These foundations do not provide the required flexibility in the longitudinal direction required for integral abutments. Also consider semi-integral abutments, rather than integral abutments, when the abutment is founded on top of or passes through MSE retaining wall reinforced backfill.

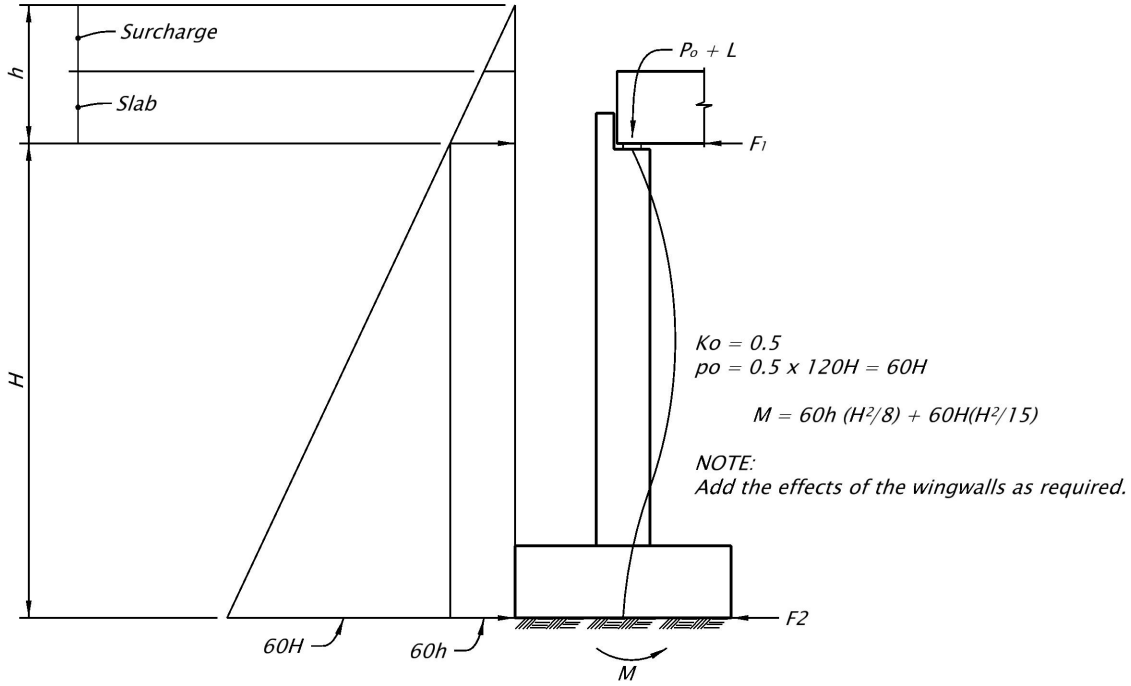
Two points that need to be evaluated on semi-integral abutments (especially on skewed bridges) are torsional forces affecting the bearings, and the effectiveness of shear keys used. When geometry requires a stiff footing, this type of construction is recommended.

For skewed bridges, consider the load path from thermal forces to the substructure. Skewed semi-integral abutments may rotate (finish condition).

1.11.2.7 Strutted Abutments

Abutments of single span bridges with the superstructure in place before backfilling may be designed using the strutting action to resist earth pressure overturning. For such abutments, apply soil pressure based on an at-rest or neutral condition of the soil. Footings for these abutments are not required to satisfy the **uniform bearing** under the dead load requirement. Investigate the bridge for the case of backfill being washed out behind one abutment, see *BDM 1.10.5.8* and *2.14.7.3.2*. For this case, use active soil pressures with no live load surcharge on the opposite abutment. A factor of safety against overturning of the whole structure of 1.25 will be considered adequate, and 125 percent of the allowable bearing pressure will be acceptable.

Figure 1.11.2.7-1 Strutted Abutment Loading



1.11.2.8 Pile Cap Abutment Details

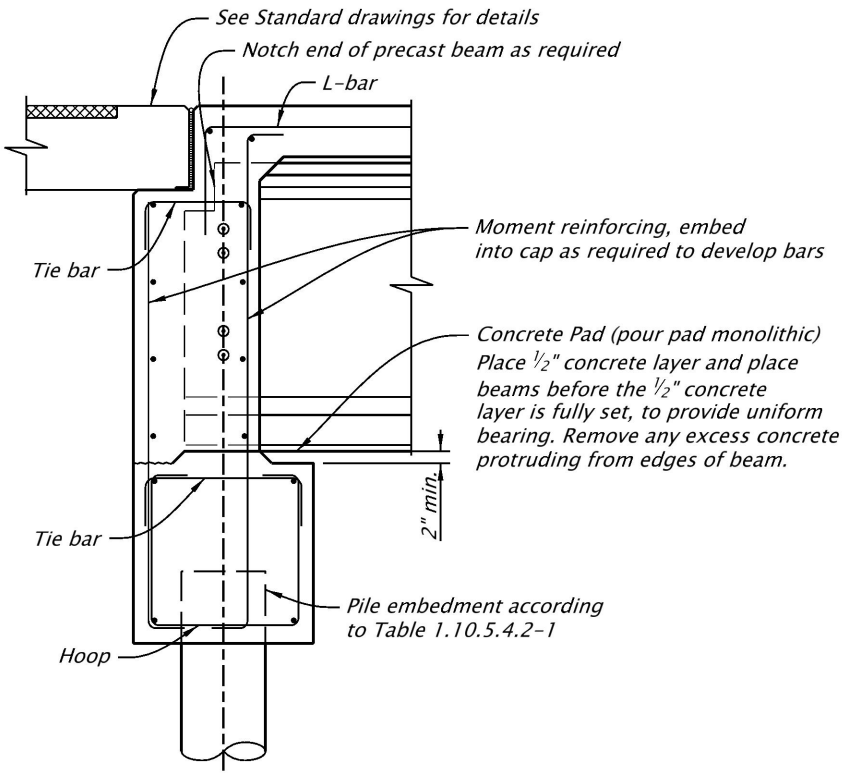
PILE CAP ELEVATIONS

Show the bottom of the pile cap elevations on the pile cap **Elevation** view. When the pile cap is sloped, show the elevation at each end.

FIXED (INTEGRAL) ACTION

Double row of reinforcing bars provides the connection between superstructure and substructure. Shear and moment are transferred. Pile embedment to develop fixity is required, when the number and size of piles are selected to resist a specified load.

Figure 1.11.2.8-1 Integral Abutment Detail

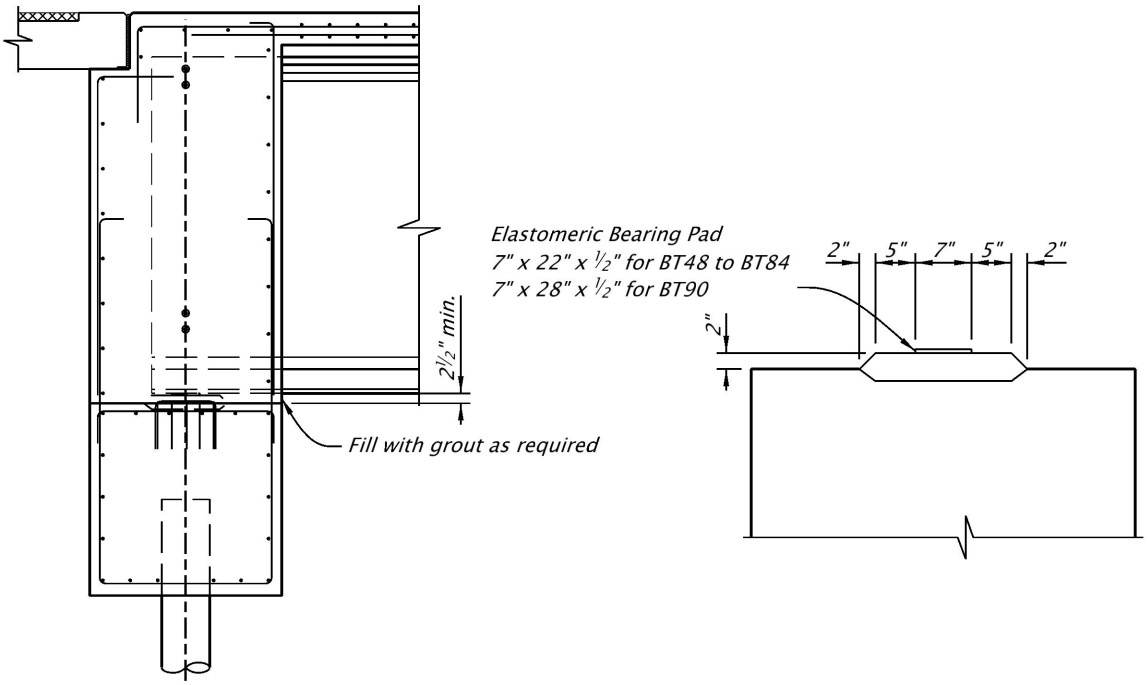


FIXED (INTEGRAL) ACTION WITH ELASTOMERIC BEARING PADS

This option allows the use of a ½ inch elastomeric bearing pad to be placed on top of the concrete grout pad. The precast beam can then be placed on top of the pad prior to the placement of the full width backwall. The beam should be placed just after a wet ½ inch grout layer has been placed under the bearing pad as specified in *BDM 1.14.1.6*. A double row of reinforcing bars provides the connection between superstructure and substructure. Shear and moment are transferred. Pile embedment to develop fixity is required, when the number and size of piles are selected to resist a specified load.

A reinforced concrete pad is required to resist temporary bearing loads. Hand placement of grout under the bottom flange of the beam may be required to fill the 2½ inch gap.

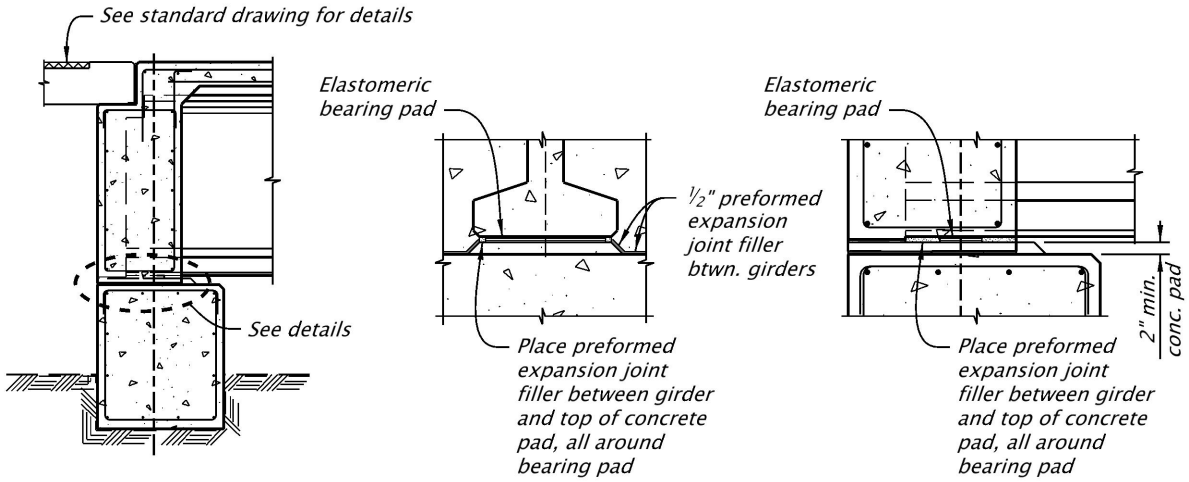
Figure 1.11.2.8-2 Grout Pad Detail



The performance of the ½ inch bearing pad under the vertical load and rotation resulting from deck load and diaphragm load was evaluated according to *LRFD 14.7.6.3.5b* for BT48 to BT90 girders. Beam weight was not included in the end rotation calculations because the wet grout layer placed below the elastomeric pad at the time of beam placement eliminates any rotation of the pad due to beam end rotation from beam dead load.

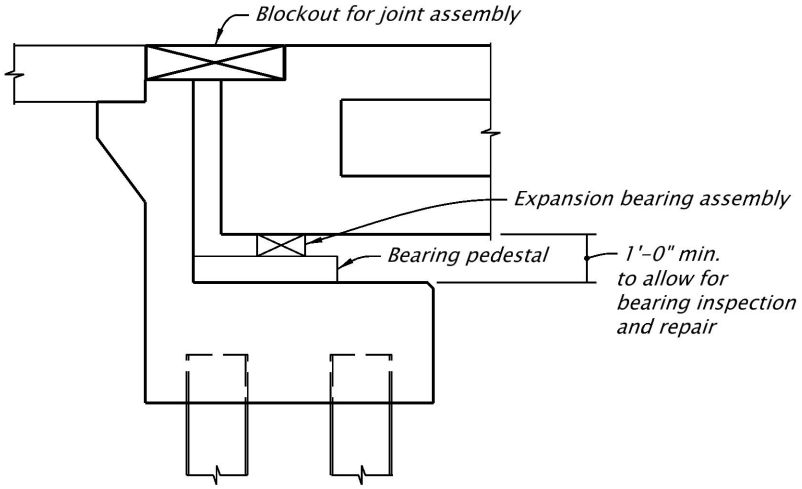
Expansion allowed (nominal amount of movement) – No reinforcement is provided between the superstructure and substructure. This type is appropriate when nominal movement is expected on a non-yielding type of foundation.

Figure 1.11.2.8-3 Bearing Detail



Expansion allowed (movement allowed as required) - No reinforcement is provided between the superstructure and substructure. This type is appropriate when movement needs to be accommodated in the design. Various types of bearings and joints can be used for the movement required.

Figure 1.11.2.8-4 Expansion Details



1.11.2.9 Abutment Details for Prestressed Slabs

See *BDM Appendix 1.11* for Prestressed Slab End Bent Design/Detail Sheets for more details.

SHALLOW ABUTMENTS (PILE CAP) – PRECAST SLAB OR BOX

Most common and most economical type of end bent. It requires the least amount of excavation and cast-in-place concrete.

Figure 1.11.2.9-1 Shallow Abutment - Precast Slab or Box detail

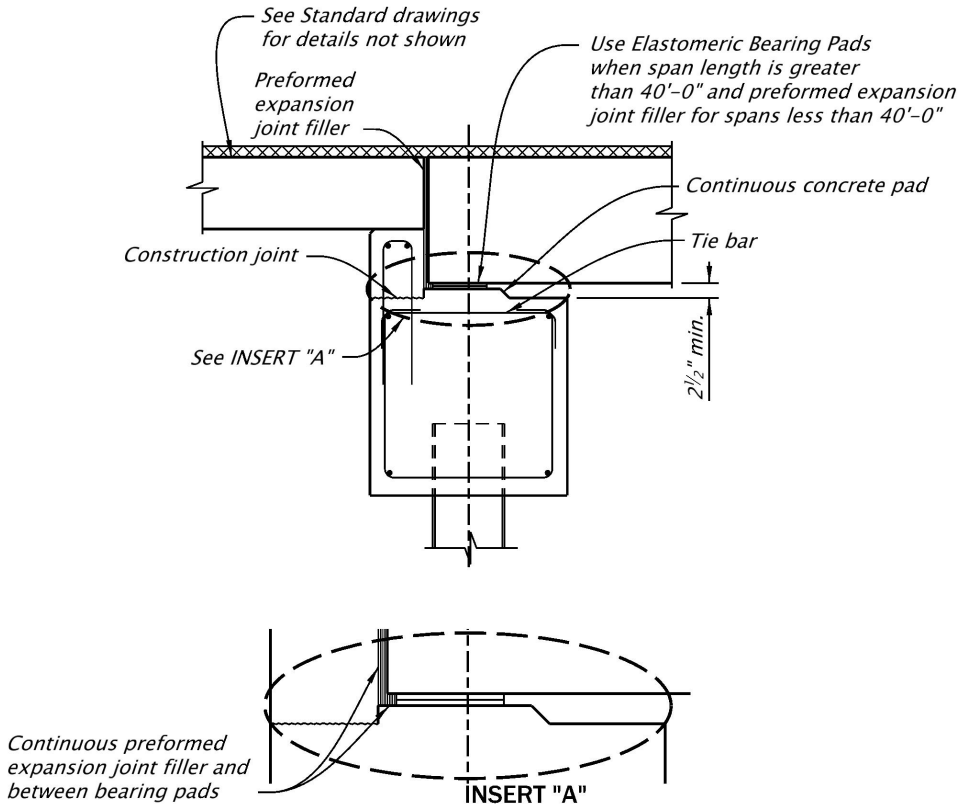
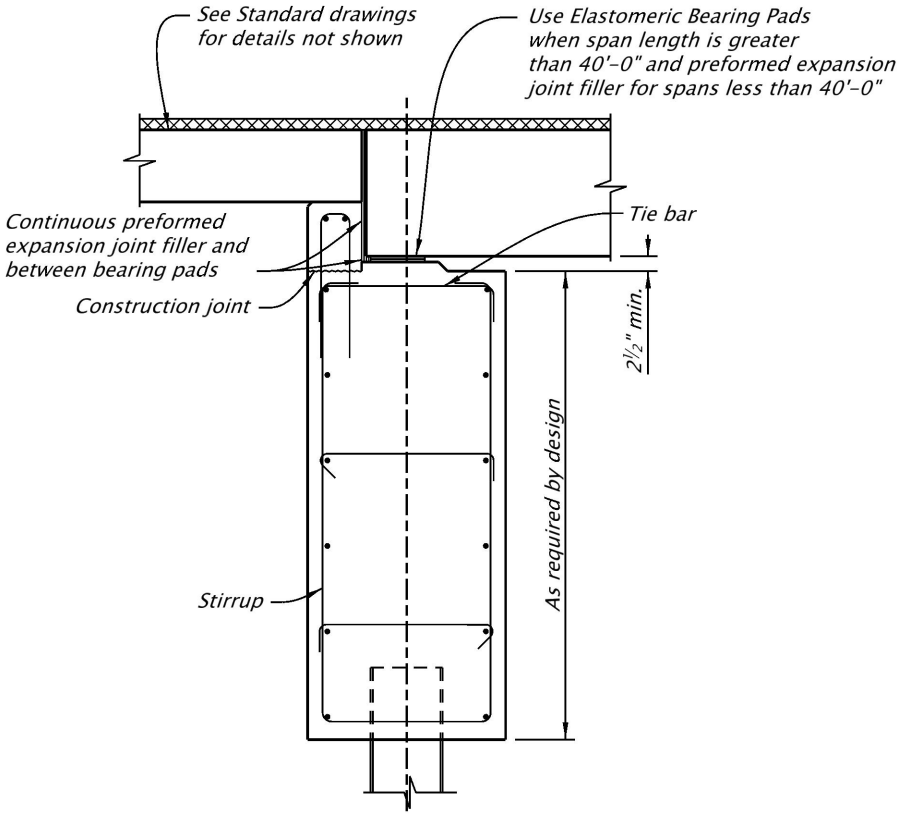


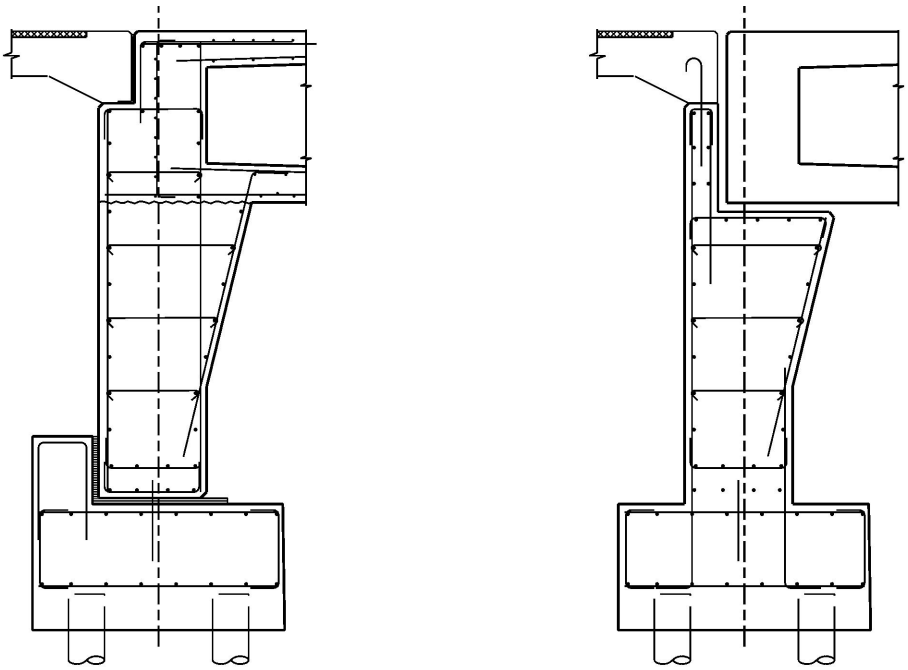
Figure 1.11.2.9-2 Partial Depth Abutment - Precast slab or box detail



1.11.2.10 Forming of Backwalls for End Beams

Details should be developed that will allow the removal of forming materials. Forming materials, including expanded polystyrene must be removed. Forming material is normally not yielding and can cause cracking as the structure expands and contracts.

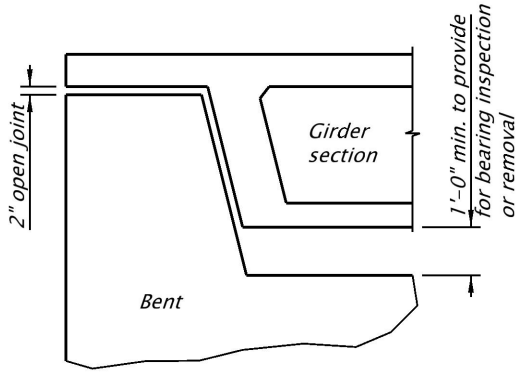
Figure 1.11.2.10-1 Backwalls for End Beam form detail



1.11.2.11 Bent Joint Details

Provide an open joint between the abutment and the deck-and-girder section, as shown below. Note on the plans of post-tensioned structures that when expanded polystyrene is used to form the joint, it must be removed before tensioning.

Figure 1.11.2.11-1 Bent Joint Detail



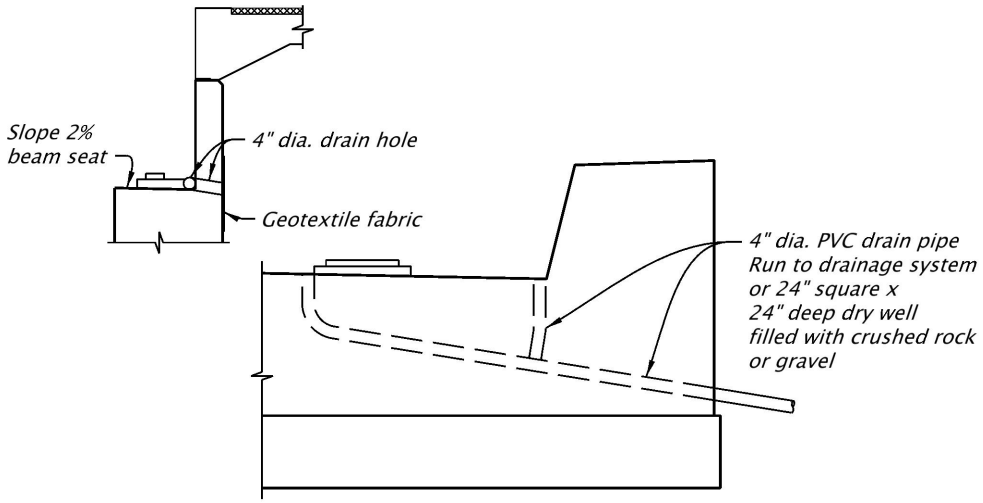
1.11.2.12 Backwall Reinforcement for Post-tensioned Structures

When detailing the vertical reinforcement for the backwalls of abutments for post-tensioned spans, the designer should take into account the location of the post-tensioning anchorages. Spacing of bars and splicing details should be such that the vertical bars do not have to be bent out of the way for the post-tensioning operation and bent back to their final positions.

1.11.2.13 Beam Seat Drainage

Slope the beam seats of abutments to drain away from the front face. Provide scuppers through the bearing pedestals and backwall or drainpipes at low points to pick up any water that might leak into this area.

Figure 1.11.2.13-1 Beam Seat Drainage Detail



1.11.2.14 Reinforced Concrete Approach Slabs

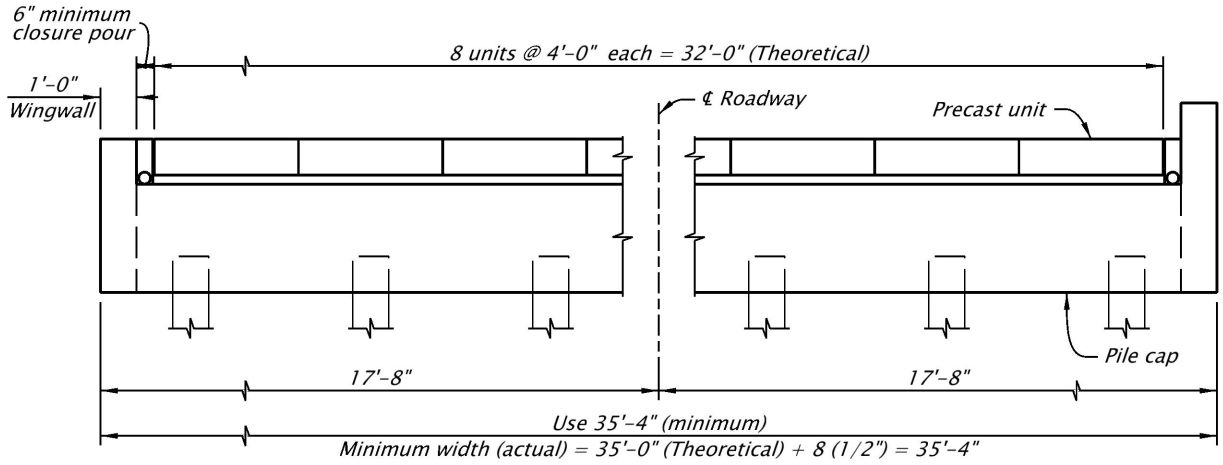
See *BDM 1.9.2.4.1* for approach slab requirement criteria.

1.11.2.15 Bent Width Provisions with Precast Units

All pile caps, crossbeams, abutments, etc. supporting adjacent precast units (such as slabs, boxes, integral bulb-T's, etc.) should be detailed for the total width of all units with an additional width of a minimum of ½ inch per precast unit. This is required because unit fit-up is not exactly true and **growth** in width occurs. The 6 inch minimum closure pour on each side of the exterior units at abutments as shown on End Bent Detail drawing may be used for

adjustment due to these misfits. The 6 inch dimension may be increased where necessary for wider roadways.

Figure 1.11.2.15-1 Bent Width Dimensions



1.11.3 Interior Bents

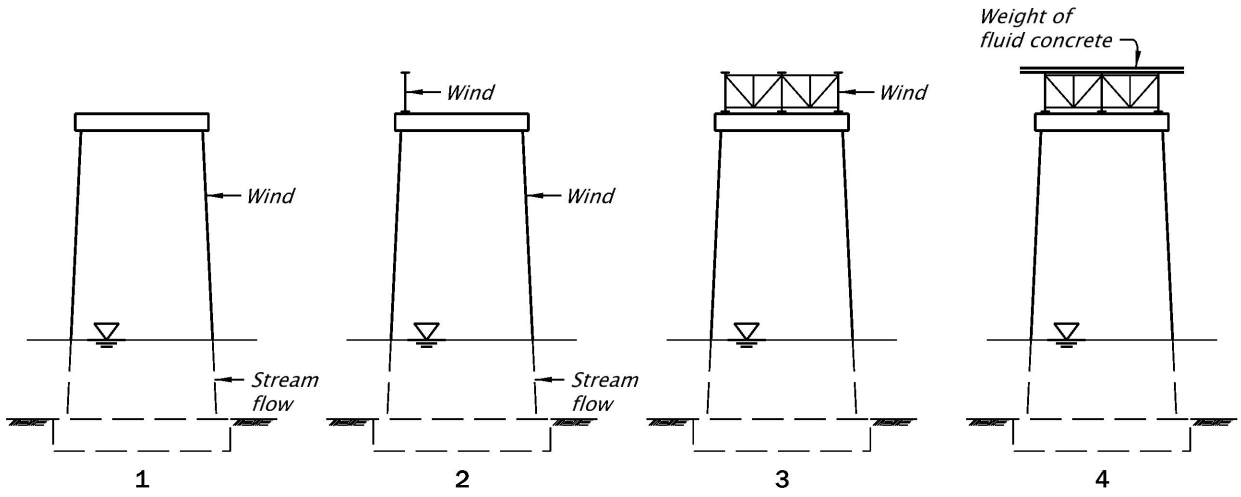
1.11.3.1 Interior Bents, Design and Detailing

DESIGN

Design structure for stability under all stages of construction. The following conditions, in particular, should be checked:

- Stream flow and wind load without superstructure.
- Dead load of one or more girders plus wind load and stream flow. Note: Contractor is responsible for stability of girder itself.
- Lateral system must be sufficient to insure stability of girders under wind load without deck.
- Top flanges must have sufficient support not to buckle under dead load of (fluid) concrete without the aid of deck forms.

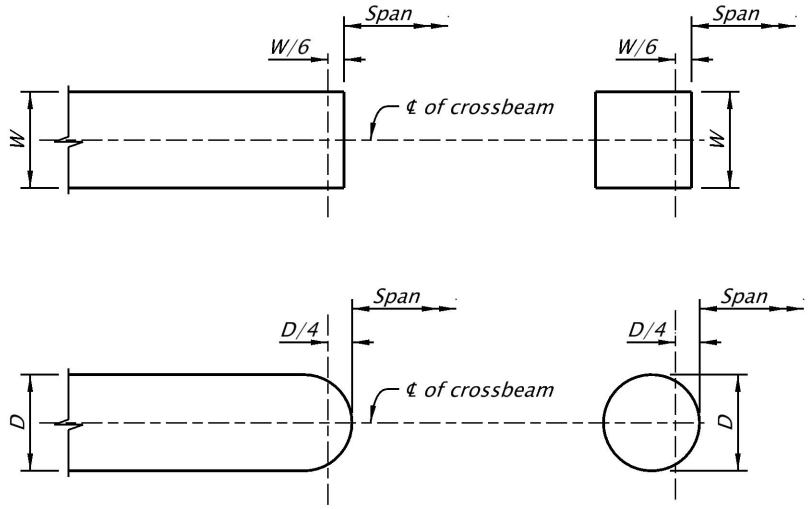
Figure 1.11.3.1-1 Construction Stability Conditions



EFFECTIVE SPAN LENGTH

When computing the maximum negative moment for a crossbeam on a column or pier, the crossbeam may be considered to be supported by a concentrated reaction, the distance show in *Figure 1.11.3.1-2* inside the face of the column or pier.

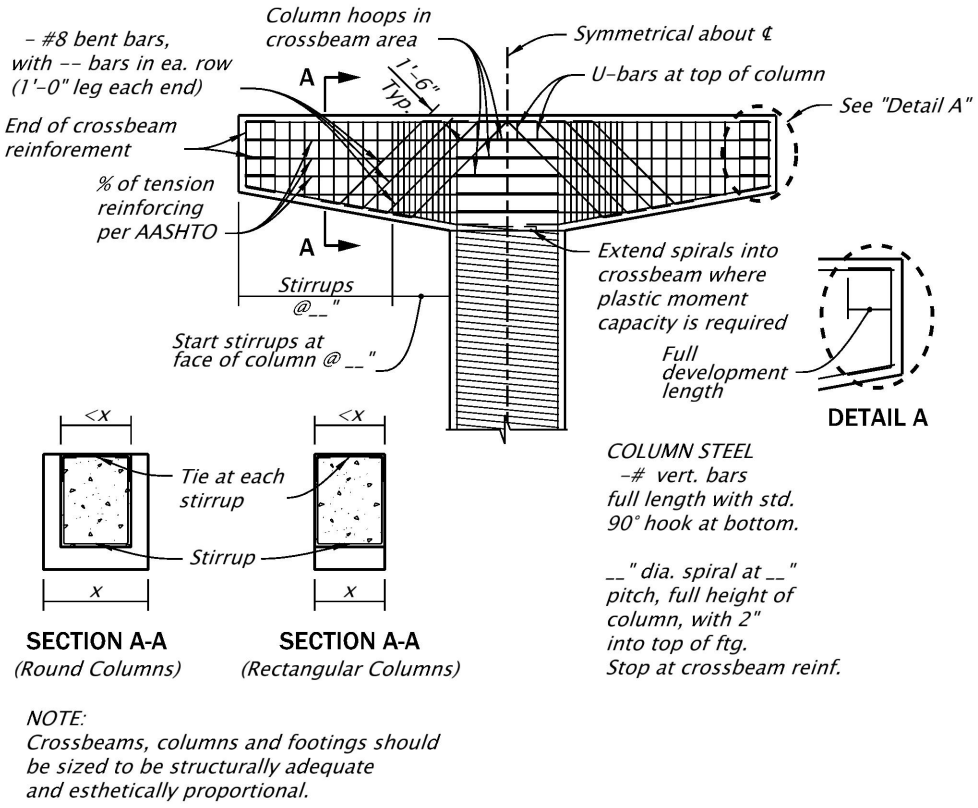
Figure 1.11.3.1-2 Effective Span Length



DETAILING

Provide all dimensions and details necessary for the reinforcing steel fabricator and contractor to construct it.

Figure 1.11.3.1-3 Structure Detailing Requirements



See *BDM 1.11.3.5* and *BDM 1.11.3.6* for details of column reinforcing.

1.11.3.2 Interior Bent Details for Prestressed Slabs

See *BDM Appendix 1.11* for Prestressed Slab Interior Bent Design/Detail Sheets.

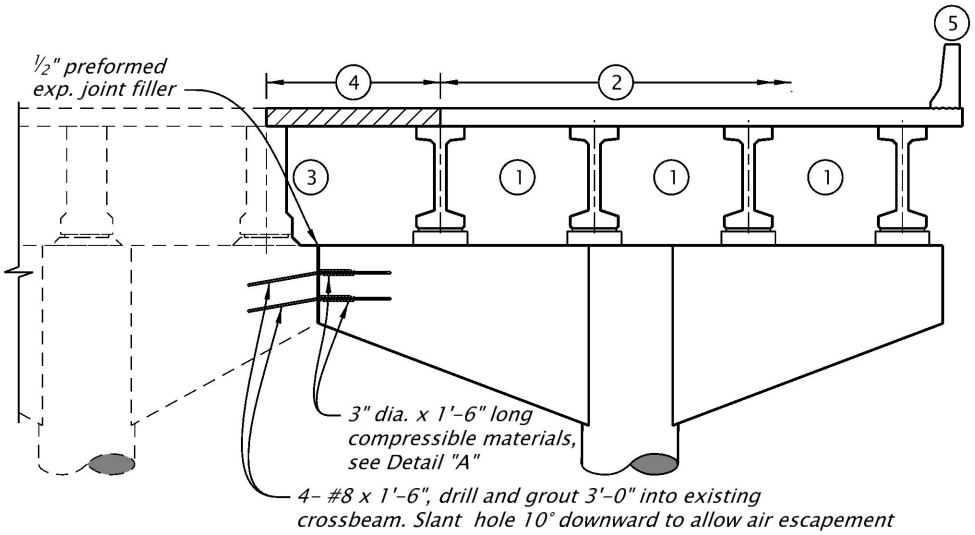
1.11.3.3 Structure Widening, Interior Bents

Generally, connections between structure bents should be detailed to tie the structures together, but prevent dead load and concrete shrinkage loads from being transferred to existing bents.

Example details are shown in *Figures 1.11.3.3-1* and *1.11.3.3-2*.

The method below allows the new crossbeam to deflect during the construction loadings with minor load transfer to the existing crossbeam.

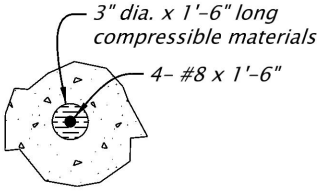
Figure 1.11.3.3-1 Structure Widening Detailing Example



ALTERNATE CROSS BEAM CONNECTION

POUR SCHEDULE
(INCLUDING CLOSURE POUR)

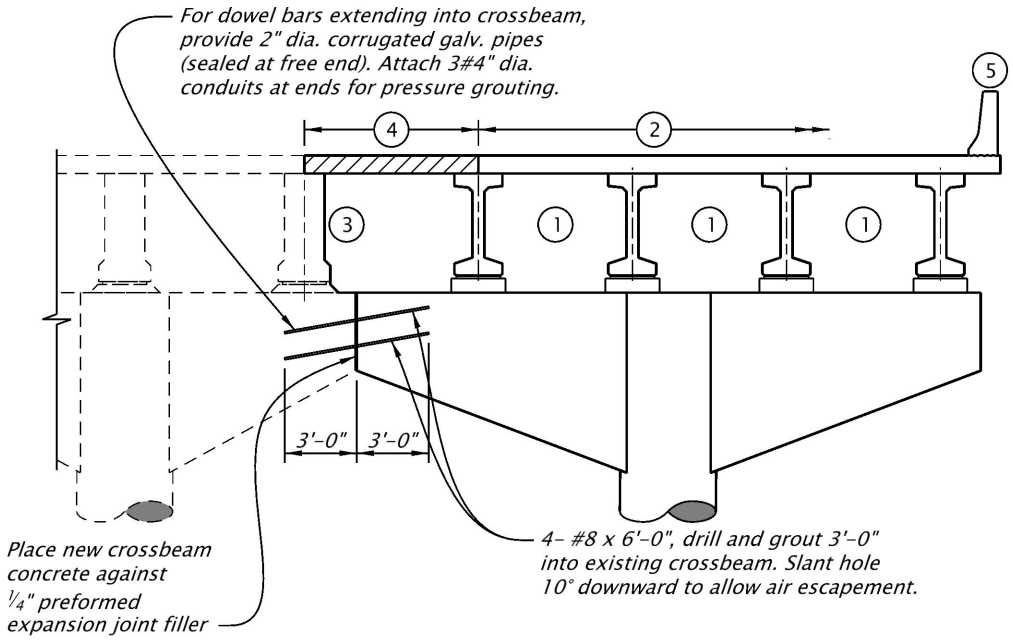
1. *Make pour in end beams and diaphragms.*
2. *Make pour in deck slab. Delay pour (2) a min. of 3 days after pour (1). A transverse deck construction joint may be made at any diaphragm beam. Delay pouring adjacent deck sections a minimum of 36 hours.*
3. *Make pour in end beams and diaphragm of closure pour section.*
4. *Make pour in deck slab of closure pour. Delay a minimum of 3 days after pour (3).*
5. *Make pour in bridge rail.*



DETAIL "A"

The method in *Figure 1.11.3.3-2* allows the widening construction to be completed before the connecting bars are grouted and able to transfer loading from the new crossbeam to the existing crossbeam.

Figure 1.11.3.3-2 Structure Widening Detailing Example



CROSS BEAM CONNECTION AND CLOSURE POUR DETAIL

POUR SCHEDULE (INCLUDING CLOSURE POUR)

1. *Make pour in end beams and diaphragms.*
2. *Make pour in deck slab. Delay pour (2) a min. of 3 days after pour (1). A transverse deck construction joint may be made at any diaphragm beam. Delay pouring adjacent deck sections a minimum of 36 hours.*
3. *Make pour in end beams and diaphragm of closure pour section.*
4. *Make pour in deck slab of closure pour. Delay a minimum of 3 days after pour (3).*
5. *Pressure grout dowels in crossbeam.*
6. *Make pour in bridge rail.*

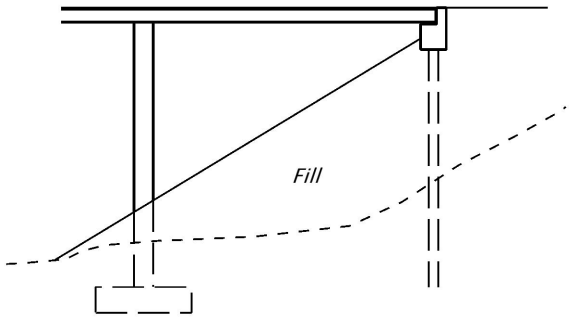
1.11.3.4 Columns in Slopes

Consider situations where new fill could exert lateral pressure against bents other than the end bents.

C 1.11.3.4

Such situations may require special construction sequence notes and special footing design including battered piling.

Figure 1.11.3.4-1 Additional Column Loading Situations



1.11.3.5 Column Design

C 1.11.3.5

1.11.3.5.1 General

See *BDM Appendix 1.2* for column loading criteria for vehicular impact, depending on type and location of barrier used (ODOT Instructions for *LRFD 3.6.5*).

For column designs controlled by seismic loading, provide shear and confinement reinforcement detailing according to *AASHTO Guide Specifications for LRFD Seismic Bridge Design, Section 8.6* as amended by *BDM 1.17.2.6*.

Ensure adequate space for personnel access for tying transverse reinforcing and inspection.

Use a concrete cover shown in *Table 1.5.5-2* to determine the core diameter and area of columns for the equations in *LRFD 5.6.4.6* and *LRFD 5.11.4.1.4*.

Where columns are supported by drilled shafts, use a non-contact splice as shown in *Figures 1.10.5.5-1* or *1.10.5.5-2*. Ensure column diameter is less than shaft diameter according to *BDM 1.10.5.5(1)*. Provide confinement reinforcement meeting the requirements in *AASHTO Guide Specifications 8.8.11* for column segments extending into drilled shaft as shown in *Figures 1.10.5.5-1* and *1.10.5.5-2*.

Specify *ASTM A706* reinforcement for vertical column reinforcing bars.

Specify ¾ inch maximum aggregate size in footings, columns and crossbeams. To maintain the shape of the spirals, use a maximum vertical bar spacing of 8 inches.

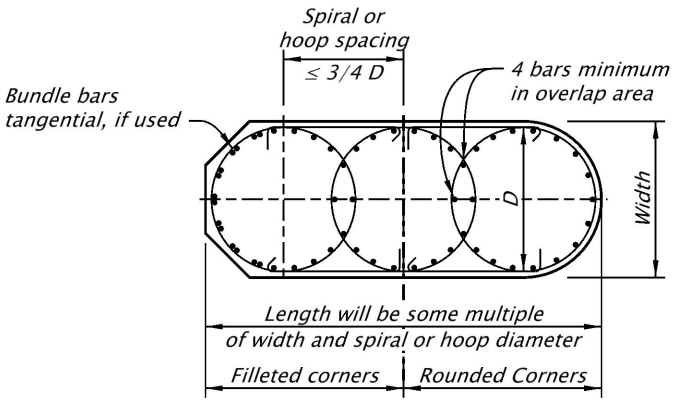
1.11.3.5.2 Non-Circular Column

Use multiple interlocking spirals or hoops for non-circular columns. Use 0.75 spiral or hoop diameters as the maximum center-to-center spacing of spirals or hoop. Closer center-to-center spacing of spirals or hoops is possible but would reduce the access space for tying and inspection.

Place at least four vertical bars within the overlap area.

See *Figure 1.11.3.5.2-1* for multiple interlocking transverse reinforcing details.

Figure 1.11.3.5.2-1 Multiple Interlocking Transverse Reinforcing Details



Design corners to be expendable in an earthquake, by detailing the rebar so that it is not developed within the core.

Orient bundled bars tangentially (both bars touching the spiral or hoop).

Corners will normally be filleted or rounded. Using rectangular corners would require nominal corner vertical bars with ties. Such ties may interfere with bar tying and inspection.

Multiple concentric rings of bars are not a constructible option with multiple interlocking transverse reinforcing but may be used in detailing of circular columns.

1.11.3.5.3 Vertical Bar Splices

Do not splice vertical column bars for columns less than 30 feet in length (no footing dowels).

For longer columns, splice at mid-height within the middle half of the column and outside the plastic hinge regions. See *Figure 1.11.3.5.3-1*. Lap splice is allowed for #11 bars and smaller.

Use Type 2 mechanical splice for #14 and #18 bars. Specify a concrete clear cover of 3 inches, when mechanical splices are anticipated in columns reinforced with #14 and #18 bars.

For bars up to #11, when the concrete clear cover in *Table 1.5.5-2* is specified for column steel reinforcing, no adjustments for the clear cover are needed to account for the larger size of mechanical splices. However, the clear spacing between bars including the mechanical splices needs to meet the minimum clear spacing requirements according to *LRFD 5.10.3*.

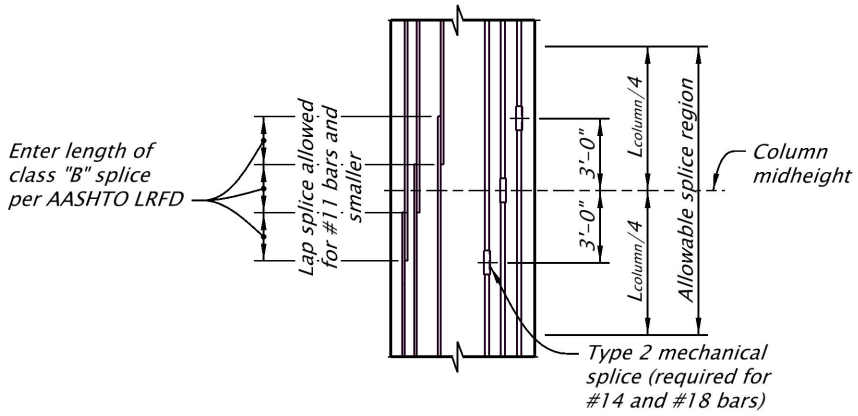
Use the diameter of mechanical splices shown in *Table 1.11.3.5.3-1* for reinforcing details. Ensure that the requirements for minimum clear spacing between bars are met.

Type 2 mechanical splice is required to develop at least 125 percent of the specified minimum yield strength and 100 percent of the specified tensile strength of the reinforcing bars. The development requirements may require 180 degree hooks of the column verticals in the cap beam. Pay attention to how the column verticals, extended spirals, bottom cap beam bars, and post-tensioning ducts all fit together.

Table 1.11.3.5.3-1 Mechanical Splice Diameter for Use in Reinforcing Details

Bar Size	Bar Diameter (in.)	Mech. Splice Diameter (in.)
#7	0.875	2.50
#8	1.000	3.00
#9	1.128	3.50
#10	1.270	3.50
#11	1.410	3.75
#14	1.693	4.50
#18	2.257	4.75

Figure 1.11.3.5.3-1 Vertical Bar Splices



1.11.3.6 Column Transverse Reinforcing

Use spirals or hoops for column transverse reinforcing. Spirals are available up to #6 bar size. Use hoops for #7 and #8 bars.

Use deformed ASTM A706 grade 60 for spirals and hoops.

Approved splice methods for transverse reinforcing steel include lapped, lap-welded, butt-welded, and mechanical splices. The approved splice methods and termination details are shown in *Figure 1.11.3.6-1.*

Lapped splices may be specified for spirals only when the spiral diameter exceeds 3 feet.

For spirals up to #6, when the concrete clear cover in *Table 1.5.5-2* is specified for column steel reinforcing, no adjustments for the clear cover are needed to account for the larger size of mechanical splices.

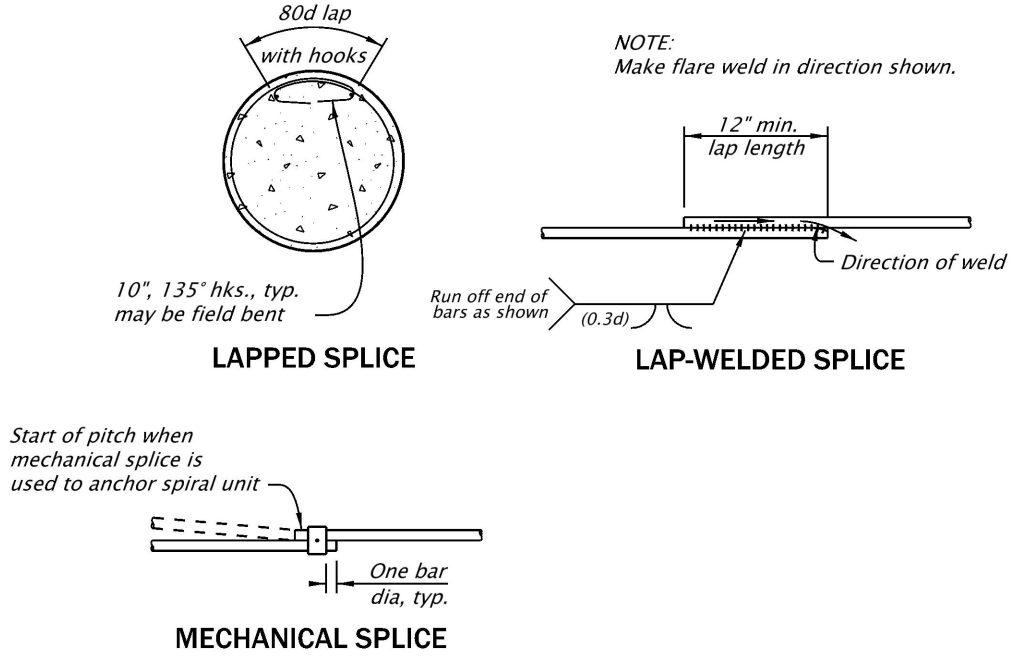
C 1.11.3.6

Hoops can be bundled. Bundled spirals are not common.

Avoid use of lapped splices for columns smaller than 3 foot because of the hooks. The hooks inhibit access for tying and inspection inside the column core and cause construction challenges. While casting concrete, the tremie may get caught in the protruding hooks, making accessibility to all areas and its withdrawal cumbersome.

ASTM A706 is formulated to be weldable so submission of chemical analysis is unnecessary. It is also preferred because it is the most ductile. ASTM A706 deformed bar coils have a weight of 3000 pound to 4500 pound, depending on the size of the bar.

Figure 1.11.3.6-1 Transverse Reinforcement Splice Methods



NOTE A:
Use ASTM A706 for all welded splices. For spiral termination, anchor spirals at each end with one extra turn and lap-welded splice to itself. Where permitted on plans, provide closed hoops conforming to the requirements of this detail. Lapped splice is not allowed within 1/6 of the column height, max. column cross sectional dimension, 18" from top of footing or bottom of cap beam, or in columns with spirals less than 3'-0" in diameter. Weld splices must conform to AWS D1.4.

1.11.3.7 Column Transverse Reinforcing Steel Details in Crossbeam and Footings

C 1.11.3.7

Extend spirals or hoops a minimum 2 inches below the top of the footing or to the bottom of the crossbeam. Specify a 4-inch maximum gap between the transverse reinforcing inside crossbeams or footings and the column transverse reinforcing.

The 4 inch gap is used to facilitate placement of the top or bottom mat of reinforcement depending on the member adjacent to the column.

Extend the transverse reinforcing inside crossbeams or footings as far as practical.

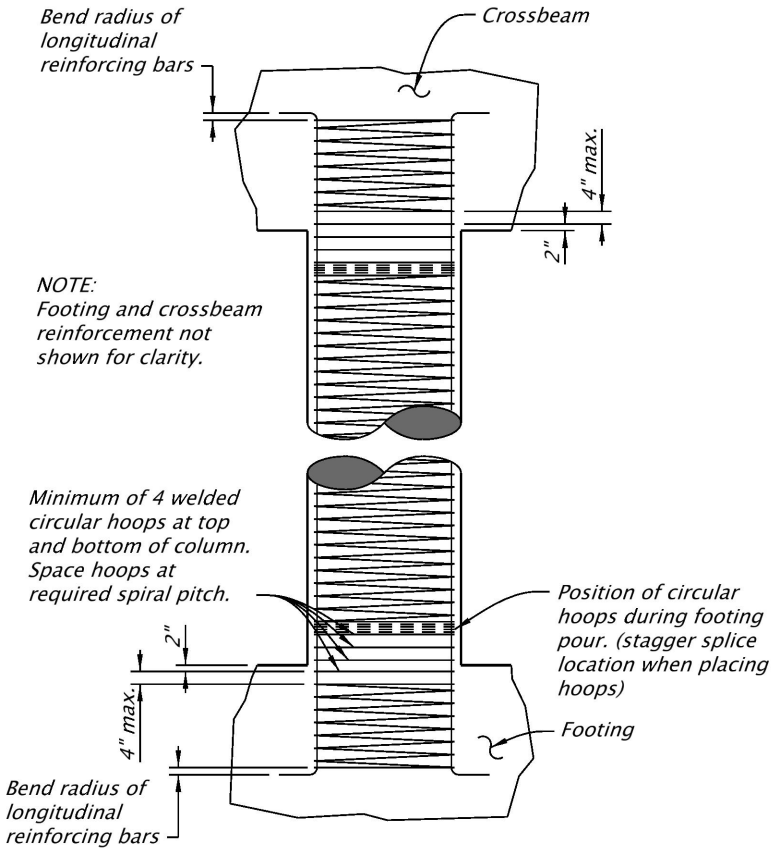
The bend radius of the column longitudinal bars controls the length of transverse reinforcing inside crossbeams or footings.

See *Figure 1.11.3.7-1* for transverse reinforcing details at top and bottom of column. Place column reinforcing steel hooks on top of the bottom mat footing reinforcement.

Specify one half of longitudinal column reinforcing to have the hooks placed inward toward the center of the core for 4.5-foot columns or larger. For columns smaller than 4.5 feet, specify all hooks to be placed outward.

The required hook length for larger-size bars could cause bar placement conflict.

Figure 1.11.3.7-1 Transverse Reinforcing Details at Top and Bottom of Column



1.11.3.8 Supplemental Transverse Reinforcement

Use hoops and ties only to supplement transverse reinforcement for architecturally shaped columns.

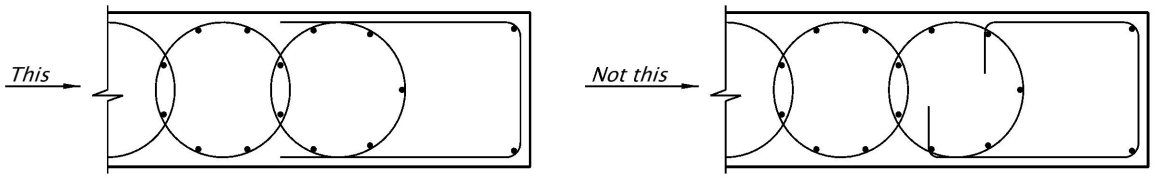
Terminate supplemental hoops and ties without the normal extension (hooks) into the interior mass of the column concrete. Detail so they do not add undesired stiffness and strength.

C 1.11.3.8

The supplemental transverse reinforcement provides some confinement to concrete that is expendable in a major seismic event.

Because architectural features are expendable and are not considered in the analysis and design, their failure is allowed.

Figure 1.11.3.8-1 Supplemental Transverse Reinforcement Details



1.11.3.9 Footing Reinforcing

Provide a mat of reinforcing steel (minimum of #5 bars at 12 inch centers each way) in the top of all footings. When calculated loads require larger amounts of reinforcement, the latter controls. Also provide U-bars at 12 inch centers around the periphery of the footing.

Place the footing top mat immediately below the spiral termination. Place additional spirals below the mat (use a 4 inch spiral gap) down to the vertical bar's point of tangency. Use the same spiral pitch at all locations.

C 1.11.3.9

See *Guide Spec. 6.4.7* for footing joint shear reinforcement for Seismic Design Category (SDC) C and D.

Figure 1.11.3.9-1 Example of Footing Reinforcing

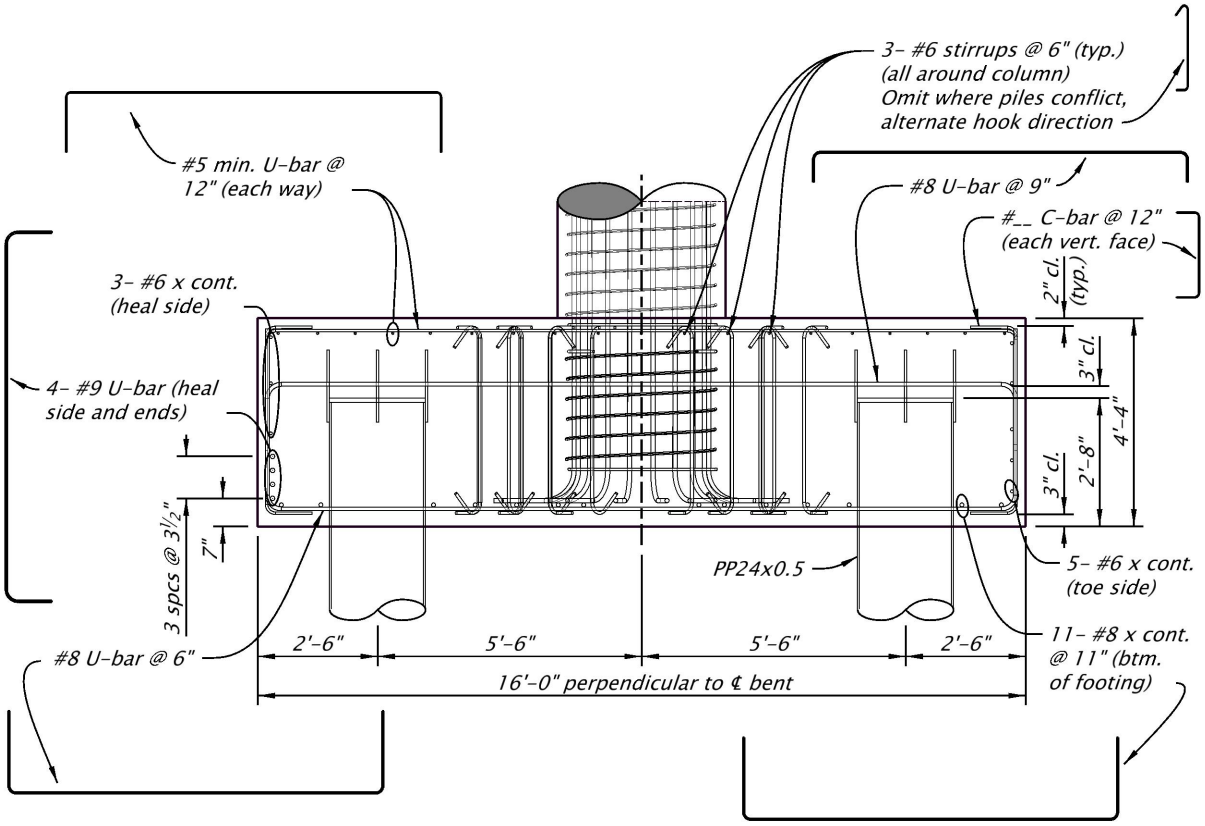


Figure 1.11.3.9-2 Example of Footing Reinforcing, Isometric View

