FOOTINGS FOR ARCH STRUCTURES

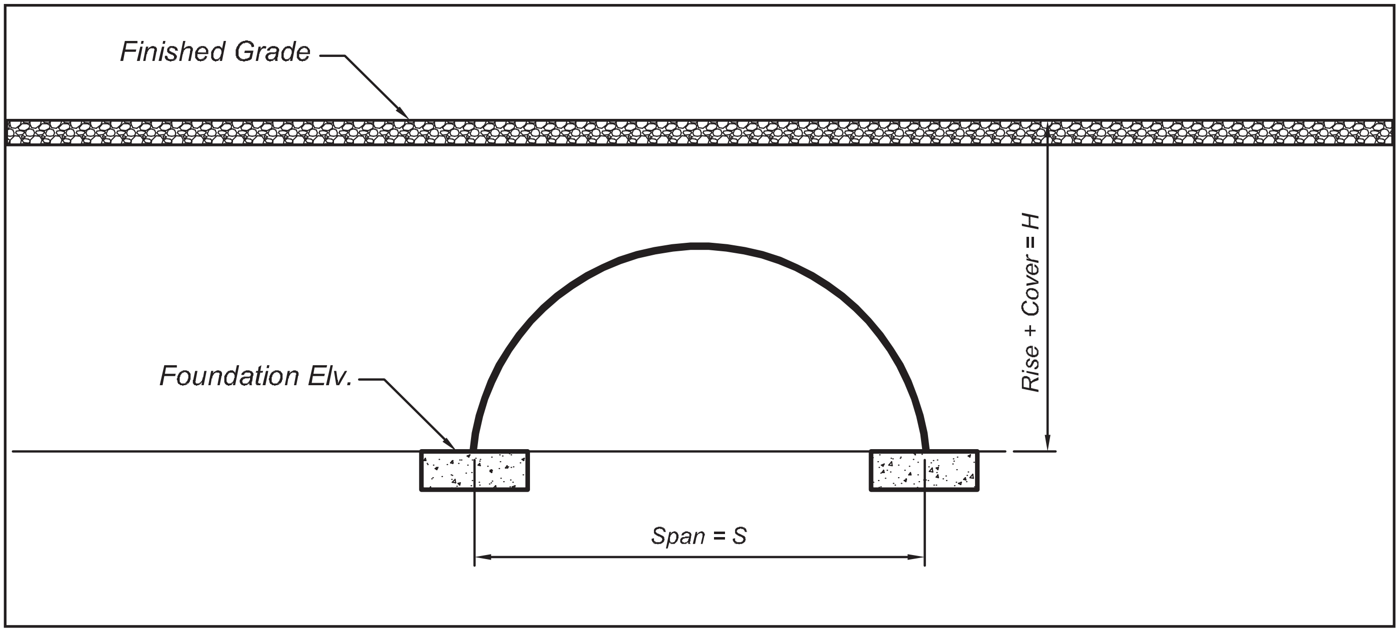


Figure 1 – Single radius arch section

Footings for Structural Plate

Similar to the design of any foundation, footing design for structural plate arches is a comprehensive engineering exercise requiring an appropriate subsurface investigation together with an understanding of reinforced concrete design and geotechnical engineering principles. The following outlines the procedure to compute footing reactions using the AASHTO Standard Specification for Highway Bridges and highlights important considerations.

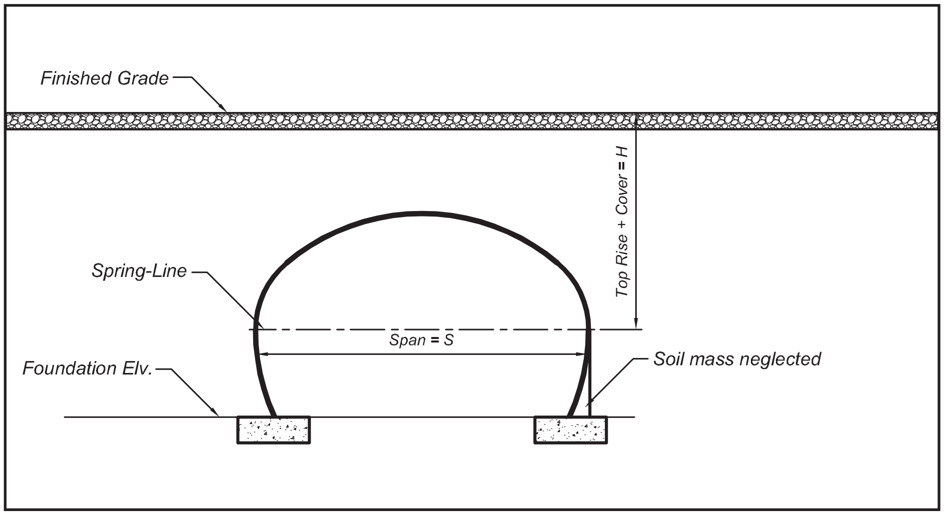


Figure 2 – Multiple radius arch section

Calculating Loads:

Dead loads: For single radius arches and arches with little or no portion of the leg turning under the spring line, the dead load on each footing can be quickly calculated by the following equation:

$$DL = ((HS - A)\gamma)/2$$

Where DL=dead load, H=total height from top of footing to finished grade, S=Span, A=total end area of the arch (see CONTECH Structural Plate Design Guide) and γ=unit weight of cover soil, typically 120 pcf. These dimensions are shown in ***Figure 1***.

A more refined approach used with arch shapes of multiple radii considers only the cover load above the spring-line or maximum span and does not include the volume of soil between the spring-line and the footing. The material weight of the structure is relatively small compared to the cover soil and is normally not included. However, considering all loads, the equation is:

$$DL = ((((C + TR)\ S) - Atop)\gamma + P)/2$$

STRUCTURAL PLATE

Where C=cover height, TR=top rise of the structure, Atop = the end area above the spring-line and P=the plate weight per foot (typically neglected). These dimensions are shown in ***Figure 2***.

Live loads: AASHTO Standard Specification for Highway Bridges Section 12.8.4.4 prescribes a method for determining the live loads applied to aluminum box culverts. Section 12.7.3.2 prescribes a method for calculating footing reactions for all other arch structures. The following practice based methodology also applies to all other structural plate arches.

HS-20 Live Load: ***Figure 3*** shows the position of the two 32 kip axles placed at the location of maximum stress. The associated 8 kip front axle is typically positioned far enough away from the crown of the arch that it has negligible influence. The 32 kip loads are distributed over 8 feet then projected down into the fill at 1:1 to the footing elevation. The live load on each footing is then calculated using:

LL = 32 kips/(8+2H) for single lane
LL = 64 kips/(8+2H) for multiple lanes

HS-25 Live Load: Follows the same procedure except the values 32 kips and 64 kips are replaced by 40 kips and 80 kips, respectively.

E-80 (Cooper) Live Load: Using a similar approach for highway loads, ***Figure 4*** shows the four most influential 80 kip axles producing maximum stress. The 80 kip loads are distributed the same way and the live load on each footing is calculated using:

LL = 160 kips/(8+2H) for single track
LL = 320 kips/(8+2H) for multiple tracks

Special Live Loads: Axle loads of off highway trucks and construction vehicles can be addressed using the above approach. In many cases the actual ground pressure and tire "footprint" of the vehicle can be

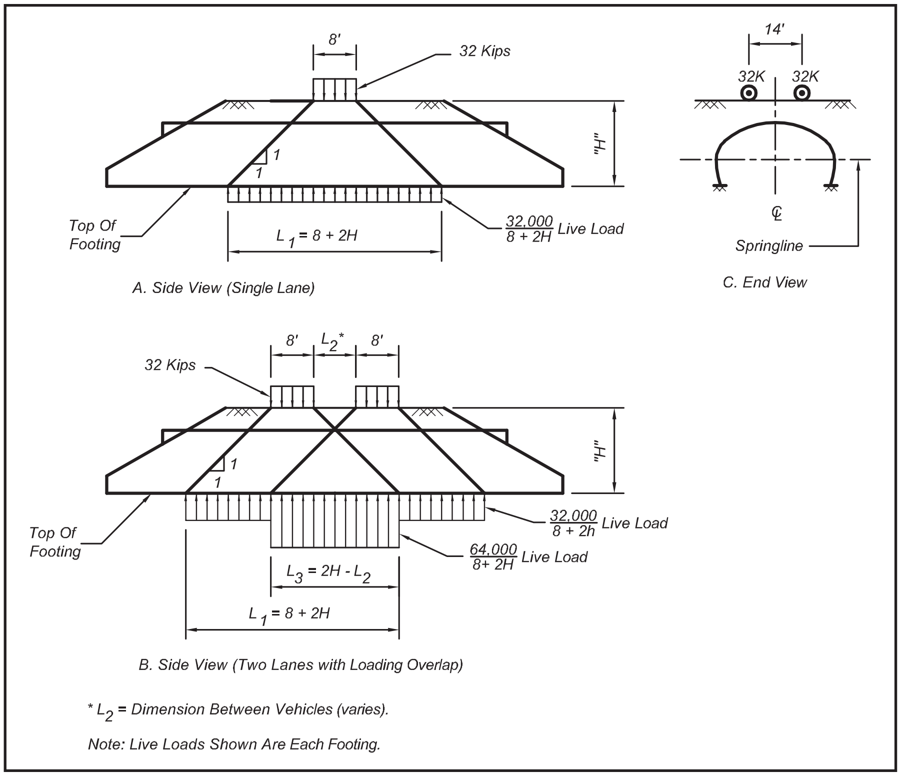


Figure 3 – HS-20 Live Load Distribution

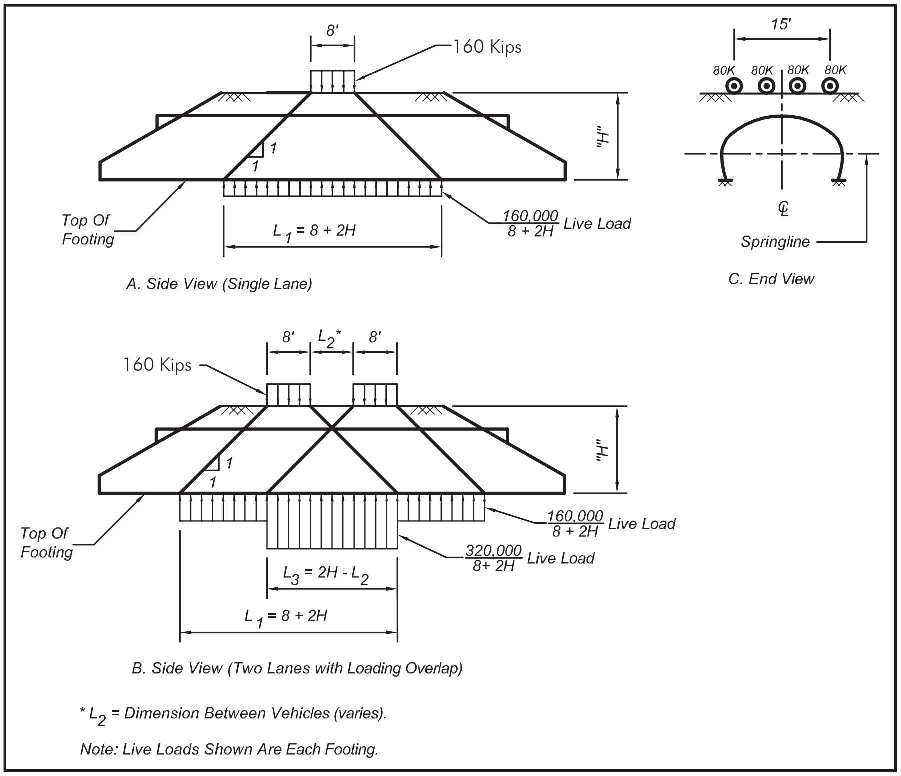
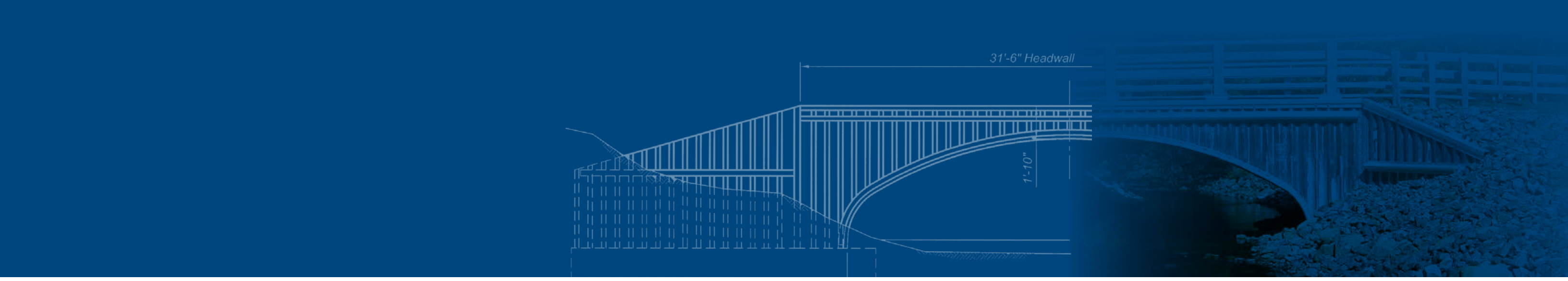


Figure 4 – E-80 Live Load Distribution



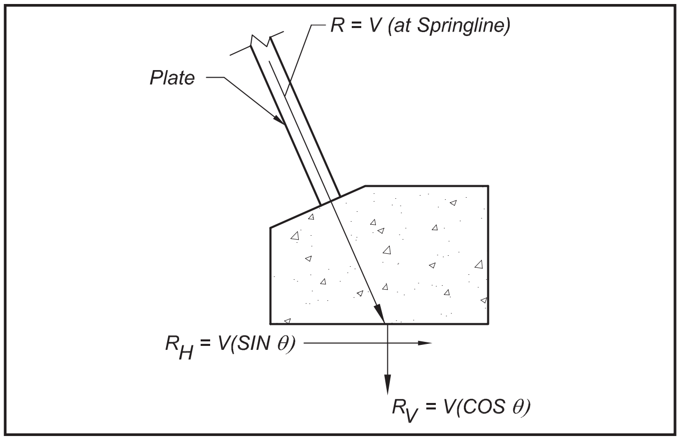


Figure 5 – Arch return angle

projected down as described. Based on the height and tire spacing, overlap can be considered and the highest resulting pressure used.

Total Load: The total load on the footing is the summation of the DL and LL. At this point, these are un-factored loads.

Note that axle loads and spacing shown for HS-20 and E-80 live loads represent the maximum, practical load influence on typical structural plate. Generally axle loads from trucks or locomotives in sequence (i.e. in the same lane or on the same track) will not increase the live load on the footing as those axle loads are far enough away to be of little influence. Typically loads that are greater than the top radius of the structure from the structure center line are far enough away to be insignificant.

Because the entire structure, including the footings, is below the ground line, impact loads are typically not used for footing design. However, culverts with less than 3 feet of cover should be evaluated per AASHTO Section 3.8.1.

Calculating Footing Reactions:

The sum of the dead load and live load is the total reaction at the top of the footing. A perfect half-circle arch will have the vertical reaction component equal to the total reaction and zero horizontal reaction component. Most structural plate arches have a return angle, either inward or outward, shown in ***Figure 5***. The components of the total reaction are:

RVert = V(cos θ)
RHorz = V(sin θ)

It is important to note the orientation of θ to consider inward or outward horizontal reaction component. Some structures have a relatively large horizontal component. Both components will be affected by the total load on the structure, so a long structure with varying underlying soil or cover conditions may warrant a footing design that also varies along the length.

Footing Design Considerations

A properly designed footing considers site-specific knowledge of all pertinent natural and man-made features including soil bearing strength, potential settlement, hydraulic scour, riparian extents, utilities and any other buried structure. Discussion of bearing strength and settlement is presented in Technical Bulletin #2, "Foundation Bearing Strength and Settlement". AASHTO Standard Specifications for Highway Bridges also provides detailed information.

In general, the need for excessively wide spread footings, piles or soil improvement indicates soft soils prone to settlement. Settlement of the adjacent backfill can induce drag-down forces on the arch. These drag-down forces should be avoided.

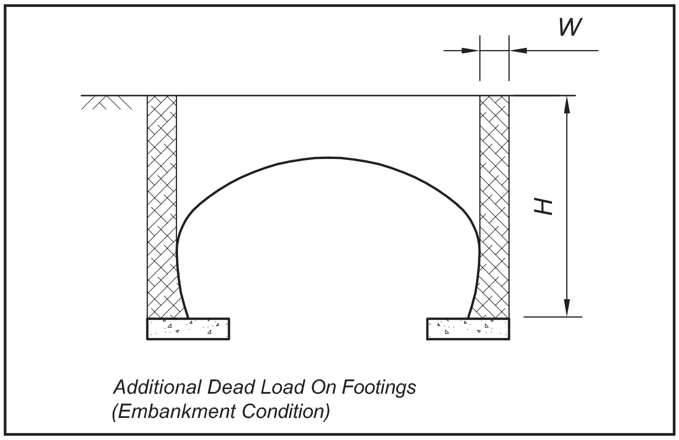


Figure 6 – Overburden on footing

Basic footing design considerations include:

1. For embankment installations where the foundation beside the arch had not previously carried the final fill height, the footing must be sized to carry the backfill overburden (soil column) that bears directly on it. (***Figure 6)***
2. Horizontal footing reactions can generally be resisted by friction between the footing and the supporting soil. In cases where friction forces are inadequate, footings can be keyed into the soil to develop passive earth pressure. Alternately struts can be incorporated between the footers. Other modification may also be appropriate.
3. Active soil pressures which are normally assumed to exert horizontal forces on the arch are offset by the radial ring compression pressures. These pressures are

accounted for in the dead load portion of the dead load reaction.

4. Footings must be either set below the scour depth or protected by an approved scour mitigation system.
5. Minor settlement under the footing is acceptable and common, so it is good practice to provide a construction joint between the footing and invert pavement, if used.

Structural Plate Footing Connection

The connection of the structural plate connection at the footing is made using either a steel base channel, extruded aluminum receiving channel or grouted slot in the top of footing as shown in ***Figure 7***. All of these connections are assumed to be pinned connections with no moment resistence. Both steel base channel or aluminum receiving channel are used to aid assembly of the plate and to provide the proper angle of the plate as it rests on the foundation to ensure proper assembled plate shape and symmetry.

As plates are assembled in the slotted footing; hardwood shims are commonly used to hold the plates in the proper orientation. Slotted footings must be filled with non-shrink, non-metallic construction grout prior to placing backfill.

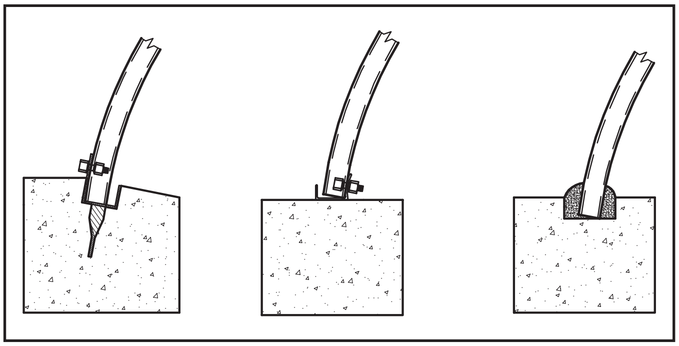


Figure 7 – Plate to footing attachment methods

This bulletin reviews some of the general engineering and design considerations applicable to CONTECH Structural Plate structures. This bulletin is not intended to address all considerations or to provide detailed design methods. Because projects differ, the considerations presented may or may not apply to a specific project. Additional considerations or an alteration of those discussed here may be necessary for a specific site, application or structure. Only the Engineer of Record can determine the suitability of these and other necessary considerations. CONTECH Structural Plate is a product of Contech Engineered Solutions.

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