


# FOUNDATION BEARING STRENGTH AND SETTLEMENT

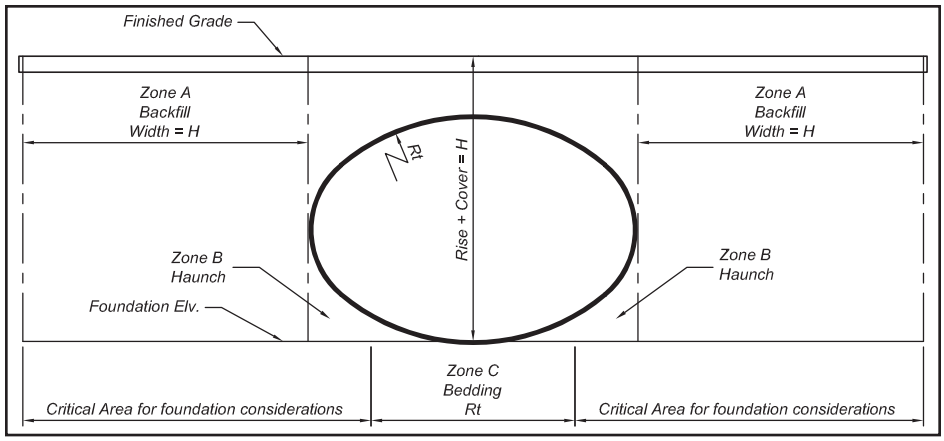


*Figure 1 – Areas of consideration shapes with invert*

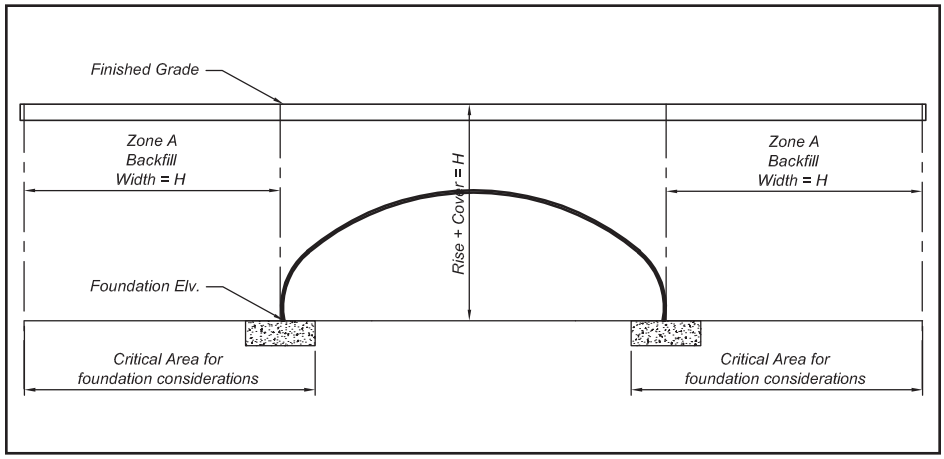


*Figure 2 – Areas of consideration arch shapes*

## Foundations for Structural Plate

Foundation considerations for CONTECH Structural Plate are analogous to those for other structures of similar size and application. CONTECH is not a design firm and makes no attempt to confirm site specific soil conditions. Exhaustive sub-surface exploration is not always required and the Engineer of Record may choose to use practical based design information. However, foundation related issues should be considered by the Engineer of Record.

## Limiting Settlement

Consolidation or settlement analysis should be performed by the Engineer responsible for the geotechnical portion of the project. Often, settlement concerns are limited to the structural plate or its footings only. Settlement of the backfill into the supporting soil layers may be a more important consideration. If settlement occurs the structural plate should be designed to settle more than the backfill beside it. This condition is particularly evident for arch shapes on pile foundations but also applies to structures with inverts supported by a granular bed. Careful investigation and proper detailing of the structural backfill zone eliminates drag down forces that can develop when the backfill settles more than the structure.

## Bearing Strength and Settlement

If a higher allowable bearing is achieved by preloading the soil under the foundation or the site is prone to consolidation, the structural plate should be designed to settle more, relative to the backfill around it. As a practical matter, settlement of the completed structure, including the structural backfill zone, must be limited to maintain line, grade, clearance, structure shape, eliminate drag down forces and minimize cracking in the footings. In summary, the backfill zone needs to be stiffer than the structural plate.

## Critical Foundation Design Areas

The foundation design must consider the soil directly below the foundation and the backfill zone extending beyond the spring line to a distance "H" shown in ***Figures 1 and 2***. Controlling settlement of the backfill and embankment in this area helps to ensure adequate backfill support.

1. Settlement of the structure and the backfill within Zone A should be minimal. Differential settlement between the structure and the backfill should be limited to 1 inch.
2. Settlement along a concrete footing must be limited considering cracking of the concrete, shear capacity and slope.
3. Differential settlement between footings or across the structure adversely affects the shape and symmetry of the structural plate. For long-span shapes AASHTO requires differential settlement ($\Delta$) to be $< 0.01 \times (\text{span})^2/\text{rise}$.
4. Excessively large footings, pile supports, or foundation improvement below the footings are indicators that the lower soil layer may be inadequate to support the backfill.




## Structures with Full Inverts

The foundation bedding immediately below the invert (Zone C) is generally not a concern. Ideally the bedding is softer than the critical areas beside it supporting the haunch (Zone B). The bedding should not be more firm than the haunch area. Typically if the bedding can support construction activities, it is adequate.

The haunch and backfill beside the structure are most critical. The foundation in these areas must support the radial pressure against the backfill which develops at the smaller radius side plates as a function of the column load of the backfill (H). Radial pressures at the foundation level can be evaluated by referring to AASHTO Section 12.7.4.3.

Aluminum box culverts with full inverts are treated similar to arches on spread footers except that the structure bears on the bedding foundation using a portion of the invert. If required, the portion of the invert directly below each box culvert leg (or side plate) is stiffened using supplemental plates placed on top of the full invert. This system effectively transfers live load and dead load directly to the supporting soil. Because of this and the lack of lower haunches in the box culvert shape, radial pressure is not a consideration.

## Foundation Improvement

Foundation improvement methods that show a good track record with Structural Plate include:

1. Surcharging the site to remove excessive settlements before assembly of the structural plate
2. Over excavation of the soft soil and replacement with properly compacted fill to limit settlement
3. Thick deposits of poorly densified granular soil can be excavated and replaced in properly compacted lifts. In cases where settlement is not a concern but over excavation is required to improve the allowable bearing, the use of layered geogrids can minimize the depth of excavation and volume of select fill material required
4. Vibratory or other consolidation of poorly densified granular materials.
5. Use of flowable fill or controlled low strength material (CLSM) - which is relatively lighter and stronger than in-situ soil – in the backfill zone to reduce soil pressure to acceptable levels.
6. Immediate settlement occurring during construction activities prior to assembly of the structural plate may not be a concern.

## Footing Design

Proper design of footings for arch structures requires site specific knowledge of bearing strength, settlement and scour. A general discussion of footing design is presented in Technical Bulletin #3, “Footings for Arch Structures”. Proper foundation conditions should be considered by the Engineer of Record. CONTECH provides footing reactions and pertinent pressures developed between the plate and the backfill in the haunch and side plate areas.

## Scour and Hydraulic Considerations

For arch structures in hydraulic applications, footings must be set at a depth to avoid scouring and undercutting. If such a depth cannot be provided, countermeasures such as sheeting, hard armor revetment protection, paved channel inverts or riprap should be considered.

Proper design requires detailed information including design water velocity, channel geometry and the physical properties of the foundation soils. Footing scour considerations are similar to those for bridge abutments and pile caps.

Foundation scour, bedding and backfill permeability must be considered in the design of hydraulic structures. This is especially important with structures with full or paved inverts. Uplift pressures from saturated foundation soils can be significant. Additional considerations are presented in Technical Bulletin #5, “End Treatment”.

For arch structures founded on piles, consideration must be given to scour potential of the soil zones between the pile and necessary scour countermeasures that are installed.

The AASHTO Standard Specifications for Highway Bridges and other publications address these considerations in greater detail.