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6.4 Spread footings

6.4.1 General

Footings may be supported on piles, on drilled shafts, on sound rock, or on soil. This article covers spread footings on rock for bridges and spread footings on rock or soil for other structures designed by the LRFD method. For footings on piles, see the pile article [BDM 6.2], the abutment articles [BDM 6.5.4.1, 6.5.4.2] or pier footing article [BDM 6.6.5.1.3] and, for footings on drilled shafts, see the drilled shaft article [BDM 6.3]. For spread footings for sign support structures, see the sign support structures article [BDM 10.2].

6.4.1.1 Policy overview

[AASHTO-LRFD 10.6.1.8]

For bridge projects the Bureau utilizes spread footings for abutments and piers only when the footings can be founded on sound bedrock. Those spread footings are designed for the appropriate service, strength, and extreme event limit states in accordance with the AASHTO LRFD Specifications. Based on site test data and analysis, the Soils Design Unit recommends the geotechnical parameters needed by the designer: the nominal rock bearing resistances at the service and strength limit states and the approximate footing elevations.

Spread footings for retaining walls, sign trusses, and other miscellaneous structures may be founded on soil unless rock is encountered at an elevation at or above normal footing depth. Spread footings for retaining walls shall be designed according to the AASHTO LRFD Specifications.

Spread footings for sign trusses and other structures covered by the AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals* [BDM 10.2] should be designed according to the AASHTO Standard Specifications. Spread footings for sign trusses and other structures covered by the AASHTO *LRFD Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals* [BDM 10.2] should be designed according to the AASHTO LRFD Specifications.

In all cases the designer shall consider existing foundations, utilities, and drainage when locating new spread footings [AASHTO-LRFD 10.6.1.8].

6.4.1.2 Design information

The “Report of Bridge Soundings” provided for each project site by the Soils Design Unit contains recommendations for foundation type and the soil logs needed for design. If the report recommends spread footings on rock for abutments or piers, or spread footings on soil for other structures, the report also will recommend nominal bearing resistances at the service and strength limit states and elevations of bottoms of footings.

The designer need not investigate global stability because it will be checked by the Soils Design Unit.

Generally, the designer need not check sliding if the spread footing is notched into rock as shown in Figure 6.4.4.2. If the soils report indicates a variable or sloping rock surface the designer should check applied horizontal forces against the friction capacity of the footing on rock or on additional lateral force-resisting details. If a friction check is necessary, the designer shall contact the Soils Design Unit for friction values of the footing on rock at the strength limit state and discuss the situation with the supervising Unit Leader.

The designer shall consult the Soils Design Unit as necessary for additional information and interpretations of subsurface data.

6.4.1.3 Definitions

Mass concrete is defined by ACI as “any volume of concrete with dimensions large enough to require that measures be taken to cope with generation of heat from hydration of the cement and attendant volume change to minimize cracking.”

6.4.1.4 Abbreviations and notation

M_u , factored moment applied to a footing
P_u , factored axial force applied to a footing
R_n , nominal bearing resistance of foundation material
Φ, resistance factor for nominal bearing resistance

6.4.1.5 References

American Association of State Highway and Transportation Officials (AASHTO). *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals,* 6th Edition. Washington: AASHTO, 2013.

American Association of State Highway and Transportation Officials (AASHTO). *LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*, 1st Edition. Washington: AASHTO, 2015.

American Concrete Institute (ACI). Guide to Mass Concrete (ACI 207.1R-05) 2012.

6.4.2 Loads

[AASHTO-LRFD 3.6.2.1]

Loads are transmitted directly to spread footings from bridge substructure components such as abutments and piers and from other structures such as retaining walls. Dead (DC and DW), live (LL and PL), and other loads transmitted to a spread footing shall be determined from the design manual articles for the component or structure supported by the footing as follows: abutments [BDM 6.5.2], piers [BDM 6.6.2], and retaining walls [BDM 6.7, in process].

For the design of spread footings for abutments and piers, the dynamic load allowance (IM) shall be excluded from the vertical loads and the pressures transmitted to rock [AASHTO-LRFD 3.6.2.1].

In cases where spread footings are placed below the water table, loads due to buoyancy shall be considered.

If analysis indicates a moment magnifier at the bottom of a column greater than 25 percent, the magnifier from the column shall be applied to the footing moment.

Lateral loads and eccentric loads applied to a bridge substructure component or structure will cause moment and potential for overturning at the level of the spread footing. The designer shall consider the eccentric pressure resultant on the footing and apply the limitations stated in the spread footing analysis and design articles that follow [BDM 6.4.4.1, 6.4.5.1].

6.4.3 Load application

6.4.3.1 Load modifier

[AASHTO-LRFD 1.3.2, 3.4.1]

Load factors shall be adjusted by the load modifier, which accounts for ductility, redundancy, and operational importance [AASHTO-LRFD 1.3.2, 3.4.1]. For typical bridge spread footings, the load modifier shall be taken as 1.0.

6.4.3.2 Limit states

[AASHTO-LRFD 3.4.1, 3.4.2]

For a typical spread footing, the designer shall consider the following load combinations at the strength, extreme event, and service limit states for the supported structural component [AASHTO-LRFD 3.4.1]. For design of abutment footings, the designer should use judgment to exclude any combinations that are not critical.

- Strength I, superstructure with vehicles but without wind
- Strength III, superstructure with design 3-second gust wind speed at 115 mph
- Strength V, superstructure with vehicles and with design 3-second gust wind speed at 80 mph
- Extreme Event II, superstructure with reduced vehicles and vehicular collision, ice, or hydraulic events
- Service I, superstructure with vehicles and with design 3-second gust wind speed at 70 mph

Design of the footing shall be based on the resulting critical combinations.

Except for unusual situations, such as eccentric loads during staged construction, the designer will not need to investigate construction load combinations [AASHTO-LRFD 3.4.2].

6.4.4 Footings on rock

6.4.4.1 Analysis and design

[AASHTO-LRFD Section 5, 10.5.5, C10.6.3.2.1, 10.6.3.3]

For modeling typical pier cap and column structures, the designer should assume fixity at tops of footings. For footing analysis and design the designer should create a second structural model, conservatively assuming the pier columns extend to bottoms of footings. If a column moment is magnified more than 25 percent at the column bottom, the column magnification factor shall be applied to the moment on the footing.

Nominal bearing resistances (R_n) at the service and strength limit states shall be as recommended by the Soils Design Unit.

Resistance factors for the service, strength, and extreme event limit state shall be taken from the AASHTO LRFD Specifications [AASHTO-LRFD 10.5.5].

Spread footings for abutments and piers shall be founded on sound rock and notched into rock as shown in Figure 6.4.4.2. On hard rock, the excavation shall be at least 12 inches deep and to neat lines of the footing. On soft rock, a footing shall extend at least 18 inches into the rock, with the final 12 inches of the excavation to neat lines of the footing.

Limestone and cemented sandstone are considered hard rock. Shale, uncemented siltstone, and uncemented sandstone are considered soft rock. This classification is subject to the judgment of the Soils Design Unit. By standard penetration test blow count, rock generally is classified as hard when blow counts are above 200.

Spread footings should be sized for eccentric loading at the strength limit state and checked for bearing at the service and strength limit states [AASHTO-LRFD C10.6.3.2.1].

For spread footings on rock the eccentricity of the loading at the strength limit state shall not exceed 0.45 of the footing dimension in any direction [AASHTO-LRFD 10.6.3.3].

Spread footings shall be designed by the strength design method [AASHTO-LRFD Section 5].

A spread footing shall be sufficiently thick so that the footing does not require punching shear or beam shear reinforcement.

For punching shear, the designer shall use the maximum average pressure resulting from factored vertical load (P_u) at the strength limit state.

For beam shear or moment, the designer may deduct the appropriate factored downward forces of the soil and footing, considering buoyant effects if applicable, from the factored upward forces exerted by rock.

For beam shear the designer shall use the factored bearing resistance (φR_n) at the strength limit state applied uniformly over the projecting portion of the footing. In cases where this pressure is too severe a design condition the design pressure may be reduced to the trapezoidal distribution resulting from analysis, with approval of the supervising Unit Leader. Ordinarily the designer should determine the concrete shear resistance by the sectional design model Method 1 [AASHTO-LRFD 5.7.3.4.1] where the method is applicable. However, the designer shall use Method 2 [AASHTO-LRFD 5.7.3.4.2] if required and may use Method 2 if it provides a significant advantage in minimizing footing thickness.

For checking distribution of reinforcement for crack control the designer shall use the controlling service limit state moment and the Class 1 exposure factor [AASHTO-LRFD 5.6.7].

For design of moment steel in the bottom of the footing, the designer shall use the maximum footing toe pressure resulting from factored vertical load and moment (P_u, M_u) at the strength limit state and apply the pressure uniformly over the projecting portion of the footing.

Reinforcing shall be provided in the top of a spread footing subjected to uplift.

The designer need not provide shrinkage and temperature reinforcement or skin reinforcement on the surfaces of a footing that otherwise would be unreinforced unless the footing thickness exceeds 5 feet. If the footing thickness exceeds 5 feet, the designer shall provide shrinkage and temperature reinforcement for mass concrete on sides and top of the footing [AASHTO-LRFD 5.10.6].

Many factors such as mix design, mix placement temperatures, mix geometry, ambient conditions, and curing methods can affect the thermal behavior of concrete. Based on the Bureau’s long-standing experience with mass concrete using typical mixes, materials, and construction practices in Iowa, the designer shall apply IDOT Developmental Specifications for Mass Concrete – Control of Heat of Hydration, when the least dimension of any element exceeds 4.5 feet. The designer also shall consult with the supervising Unit Leader or Bridge Project Development Engineer regarding mass concrete notes to be placed on the plans for controlling and monitoring concrete mix temperatures.

The designer need not check fatigue of reinforcement in a spread footing on rock.

6.4.4.2 Detailing

For spread footings notched into rock the limits for Class 22 excavation shall be as given in the figure note in Figure 6.4.4.2.

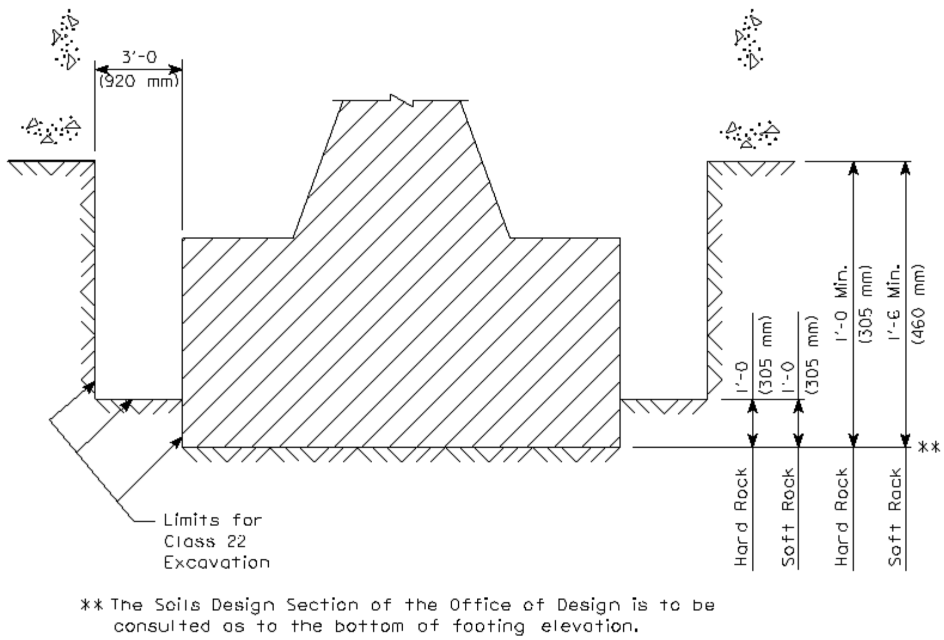

Figure notes:

- The lower portion of the notch into rock shall be to neat lines.

Figure 6.4.4.2. Footing placement on rock and limits for Class 22 excavation

The nominal bearing resistance at the service limit state and at the strength limit state shall be indicated in a note on the bridge plans.

The Bureau prefers that moment reinforcing in spread footings be developed with straight bar lengths rather than hooks. If straight bar lengths cause excessive enlargement of a footing the designer may consider hooks.

When detailing horizontal construction joints such as the joint between column and footing, the designer shall assume the ends of vertical bars rest on the construction joint and determine the bar lengths accordingly.

6.4.5 Footings on soil

6.4.5.1 Analysis and design

[AASHTO-LRFD 10.6.1.2, 10.6.3.3, Section 11]

Spread footings subject to frost heave shall have a bottom elevation a minimum of 4 feet below ground line [AASHTO-LRFD 10.6.1.2].

For spread footings on soil and designed by the AASHTO LRFD Specifications, the eccentricity of the resultant of pressure on the base of footing at the strength limit state shall not exceed one-third of the footing dimension in any direction [AASHTO-LRFD 10.6.3.3].

Spread footings on soil that support retaining walls shall be designed in accordance with the AASHTO LRFD Specifications section on retaining walls [AASHTO-LRFD Section 11].

6.4.5.2 Detailing

Reserved