4-1 Spread Footings

Introduction

The scope of this Memo is to clarify the terms and design methodology used in the Load and Resistance Factor Design (LRFD) of spread footings as specified in AASHTO LRFD Bridge Design Specifications with California Amendments (LRFD-BDS), and to improve communication between Structure Designer (SD) and Geotechnical Designer (GD).

Definitions and Notation

"Contact Surface" refers to the bottom surface of the footing located at a specified elevation, and resultant structural forces and moments are calculated at that level. Refer to Figure 1 for footing local coordinates and illustration of the following parameters used throughout this Memo:

B = Footing Width. This is the short plan dimension of the footing.

L = Footing Length. This is the long plan dimension of the footing.

M = Factored Bending Moment
M_X and M_Y are calculated at the contact surface in the local X and Y directions, respectively.
Local X axis is defined to be parallel to the long plan dimension of the footing (L).

V = Factored Shear Force:
V_X and V_Y are calculated at the contact surface in the local X and Y directions, respectively.

B' = Effective Footing Width:
Reduced footing width for an eccentrically loaded footing is calculated as the smaller of : $(B - 2e_Y)$ and $(L - 2e_X)$, where e_Y and e_X are the eccentricities (always positive) corresponding to M_X and M_Y, respectively.

L' = Effective Footing Length:
Reduced footing length for an eccentrically loaded footing is calculated as the larger of $(B - 2e_Y)$ and $(L - 2e_X)$.

$A' = B' \times L'$. Effective Footing Area.

P_{Total} = Total factored axial force
Total factored axial force is calculated at the contact surface as gross (for Strength, Construction and Extreme Event load combinations) or net (for Service load combinations).

P_{Perm} = Permanent net axial force
Permanent net axial force is calculated for LRFD permanent loads acting at the contact surface and is used to evaluate settlement under Service-I limit state load combination.

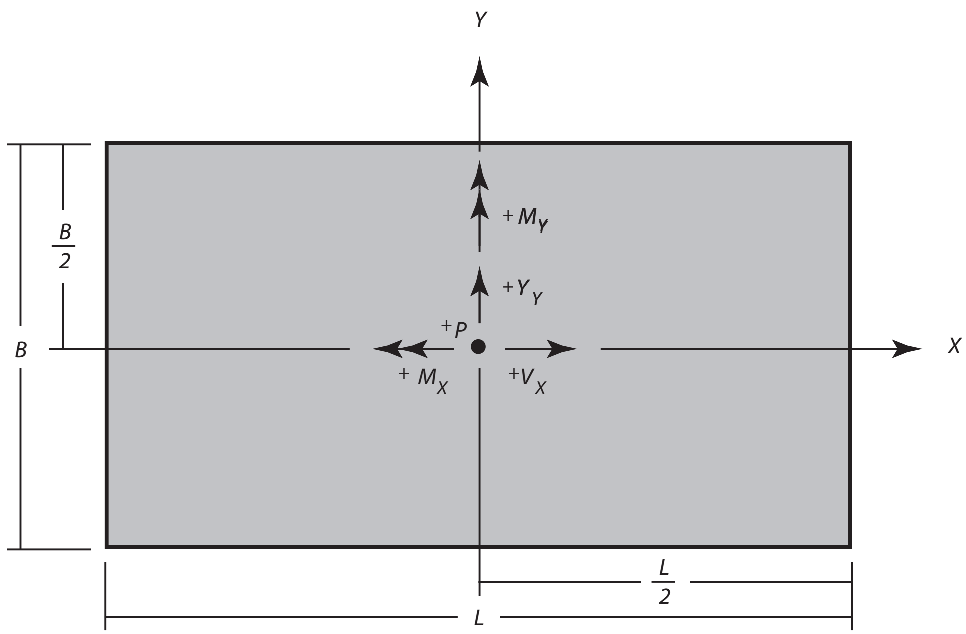

Figure 1 – Components of Moment and Shear in Local Coordinates of the Spread Footing

$q_{g,u}$ = Gross Uniform Bearing Stress
Used for footings on soil, gross uniform bearing stress is the equivalent uniform vertical stress determined by applying the vertical factored load over the effective footing area. When determining the gross uniform bearing stress, the designer must include the weight of the footing and all overburden soil from the top of the footing to finished grade with applicable load factors.

$q_{g,max}$ = Gross Maximum Bearing Stress
Gross maximum bearing stress is the maximum applied vertical stress at the contact surface when applying factored loads. The gross maximum bearing stress must include the weight of the footing and of all overburden soil from the top of the footing to finished grade with applicable load factors. Used for footings on rock, $q_{g,max}$ is based on triangular or trapezoidal stress distribution, as appropriate, on the footing area.

$q_{n,u}$ = Net Uniform Bearing Stress
Net uniform bearing stress is the gross uniform bearing stress for footings on soil ($q_{g,u}$) minus the overburden or vertical effective stress at the contact surface calculated based on grade elevation at the time of excavation for the footing. The net uniform bearing stress due to LRFD Service-I load combination is used to evaluate footing settlement on soil. The net uniform bearing stress is calculated for total factored axial forces.

$q_{n,max}$ = Net Maximum Bearing Stress
Net maximum bearing stress is the gross maximum bearing stress for footings on rock ($q_{g.max}$), minus the overburden or vertical effective stress at the contact surface calculated based on finished grade for abutments and original grade for bents. The net maximum bearing stress due to LRFD Service-I load combination is used to evaluate footing settlement on rock. The net maximum bearing stress is calculated for total factored axial forces.

q_n = Gross Nominal Bearing Resistance
Used in Strength and Extreme Event Limit States, this is the gross uniform bearing stress for footings on soil, or the gross maximum bearing stress for footings on rock that will fail the soil or rock, respectively, in shear based on a strength criterion.

q_R = Factored Gross Nominal Bearing Resistance
Used in Strength and Extreme Event Limit States, $q_R = \varphi_b \, q_n$ where φ_b is resistance factor from Section 10.5 of the LRFD BDS.

q_{pn} = Permissible Net Contact Stress
This is the net bearing stress resulting in an estimated settlement that is structurally safe and without adverse impact on serviceability. This value is calculated using total Service-I loads, irrespective of whether or not consolidation contributes to the total settlement.

Design Process

The shallow foundation structural design process includes the following steps:

1. Contact Bearing Stress Check (Sizing the footing)

Spread footings used to support abutments or bent columns or piers must satisfy the following requirements:

For Service Limit State (Settlement):

1. $q_{n,u} \leq q_{pn}$ for footings on soil
2. $q_{n,max} \leq q_{pn}$ for footings on rock

For Strength, Construction and Extreme Event Limit States:

1. $q_{g,u} \leq q_R$ for footings on soil
2. $q_{g,max} \leq q_R$ for footings on rock

2. Eccentricity Limits

All footings must be checked for tilting/rotation by SD. On competent foundation materials, the tilting/rotation is considered within acceptable limits, when the maximum eccentricity calculated based on gross axial force under Service-I Limit State load combination is limited to $B/6$ and $L/6$ for footings on soil, or to $B/4$ and $L/4$ for footings on rock. Refer to LRFD BDS 10.6.4.2 for eccentricity limits under Extreme Event Limit State load combinations.

When founded on poor or soft soils, a detailed tilting/rotation deformation analysis by GD is required in lieu of this check. SD and GD must communicate especially if non-standard or special design conditions exist.

3. Sliding Failure

For foundation material at the contact surface the internal friction angle of drained soil (φ_f) for footings founded on rock or cohesionless soil, and the undrained shear strength for footings founded on cohesive soil will be provided by the GD. SD will check sliding failure for Strength and Extreme Event Limit States load combinations per LRFD BDS 10.6.3.4 requirements.

Structural design of the footing shall start after finalizing the size of the footing. The SD will determine the required depth of the footing and also the amount and distribution of steel reinforcement.

Communication with Geotechnical Designer

Sizing a spread footing is an iterative process because the calculated Permissible Net Contact

Stress (q_{pn}) and the Factored Gross Nominal Bearing Resistance (q_R) depend on the location, dimensions and depth of the footing. To facilitate design, GD will provide these parameters as a function of the effective footing width, (B'), for a range of effective footing length to effective footing width ratios, (L'/B'), and a given footing embedment depth specified by Structural Designer.

If the support location or footing embedment depth changes during the design process, GD shall be contacted so that the geotechnical design data can be revised.

To prepare foundation recommendations and reports, GD needs foundation location, geometry, and load data from SD. Attachment No. 1 shows examples of Foundation Design Data Sheets to be included in the request for Preliminary Foundation Report (PFR) .

Attachment No. 2 (Foundation Geotechnical Data Tables) indicates the format that will be used for the transmittal of geotechnical foundation design data from GD. The communication of this data is an intermediate step in the design process. This table will not be included in the Foundation Report.

Attachment No. 3 (Bridge Foundation Loads) is an example of the detailed load data which must be provided by SD. If requested, the GD must receive the data shown in Attachment No.3 prior to the completion of the Foundation Report (FR). Attachment No. 4 shows the Foundation Design Data Sheet to be included in the request for Foundation Report.

Spread Footing Data Table

Spread Footing Data Tables shall be included in the FR and on the Contract Plans in the formats shown in Attachment No. 5.

Although Spread Footing Data Table is not necessary for contract administration purposes, its inclusion is a useful addition to the plans. With the foundation design parameters included in the table, the engineer can perform an informed inspection of the bearing material. These design parameters are also a starting point for the future design of widening and emergency projects.

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