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DESIGN OF STRIP FOOTINGS OVER SOIL REINFORCED BY RAMMED AGGREGATE PIERS

This Technical Bulletin discusses the design concepts for the structural design of strip footings supported by Rammed Aggregate Pier® (RAP) soil reinforcing elements. Conventional strip footings supported at grade are traditionally designed assuming that the subgrade soils beneath the footings provide uniform support. The installation of RAPs beneath strip footings provides for stiffer support at the pier locations resulting in a non-uniform support condition beneath the srip footing. The design of Rammed Agggregate Pier supported strip footings, therefore, must include considerations for the difference in stiffness profile and contribution of subgrade support beneath the footings.

1. DESIGN OF CONVENTIONAL STRIP FOOTINGS SUPPORTED AT GRADE

The design of shallow strip footings supported by unreinforced soil is typically performed using guidelines published by the American Concrete Institute (ACI-318). The minimum footing width (B) is determined from the uniformly distributed load (w) and allowable bearing pressure (q):

$$B = \frac{w}{q} \qquad (1)$$

where w is the distributed footing load in units of force per unit length and q is the allowable soil bearing pressure in units of force per unit area.

Because the applied wall load (w) is coincident with the uniform resisting pressure (q), the footing is not subject to bending moments along its longitudinal axis (Figure 1a).

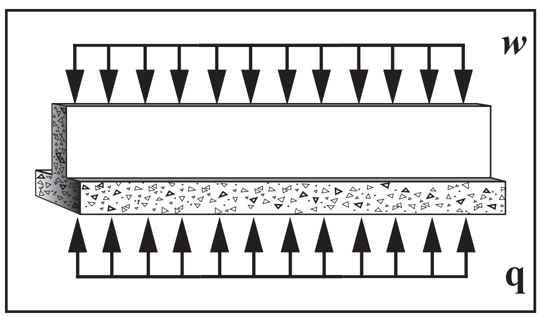

Figure 1a.
Strip Footing Supported at Grade

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2. DESIGN OF GRADE BEAMS SUPPORTED BY DEEP FOUNDATIONS

Because pile foundations are infinitely stiff compared to the unreinforced soil, the entire wall load is assumed to be resisted by the deep foundations. Typically a grade beam is designed to completely transfer all of the loads to the piles. Figure 1b shows a schematic of a grade beam supported by deep foundations. The load from the superstructure is resisted by shear forces and bending moments by the reinforced grade beam.

The maximum shear, V, and bending moment, M, are calculated using the following equations:

$$V_{max} = \frac{wL}{2} \quad (2)$$

$$M_{max} = \frac{wL^2}{8} \quad (3)$$

where:

w is the uniformly-distributed load in units of force per unit length and L is the footing length between piles.

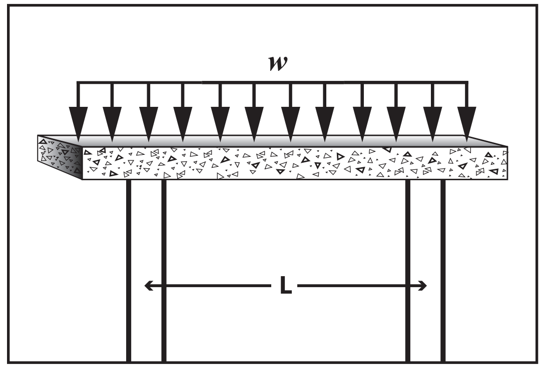

Figure 1b.
Grade Beam Supported by Pile Foundations

3. DESIGN OF STRIP FOOTINGS SUPPORTED BY RAPs

RAP supported strip footings (Figure 1c) represent an intermediate condition between conventional uniform soil-supported strip footings and pile-supported grade beams. Because the pier-soil stiffness ratio (R_s) is often in the range of 5 to 40 (Lawton and Fox 1994, Lawton et al. 1994, Lawton and Merry 2000) and because RAP elements require confinement from the matrix soil, the soil between the elements resists a portion of the applied wall load.

The shear and bending moment that develops within RAP-supported footings may be estimated as:

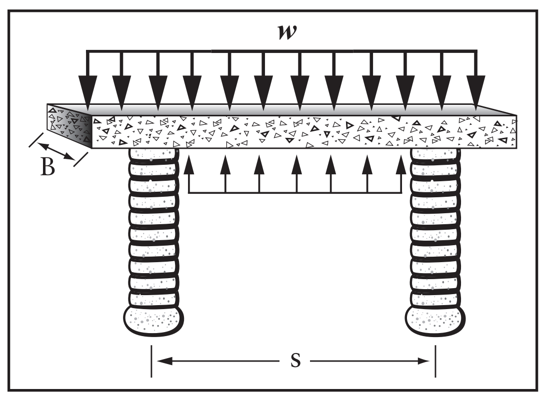

Figure 1c.
Strip Footing Supported by RAPs

$$V = \frac{w_{net} L}{2} \quad (4)$$

$$M = \frac{w_{net} L^2}{8} \quad (5)$$

Where w_{net} is the net wall load applied to the strip footing. The value for w_{net} may be computed as:

$$w_{net} = w - q_m B \quad (6)$$

where q_m is the bearing pressure resisted by the matrix soil.

Using equations of statics and the assumption that the strip footing exhibits uniform settlement, q_m (Lawton and Fox, 1994, Lawton et.al. 1994, Fox and Cowell, 1998, Wissmann, et.al., 2000) may be computed as:

$$q_m = \frac{q}{R_a R_s - R_a + 1} \quad (7)$$

where R_a is the ratio of the cross-sectional area of the RAP elements to the footprint area of the footing. R_a is estimated as $\frac{A_g}{sB}$ where s is the pier center-to-center spacing and B is the footing width. R_s is the ratio of the stiffness of the RAP element to the matrix soil, and q is the average soil bearing pressure computed as:

$$q = \frac{w}{B} \quad (8)$$

For lightly-loaded strip footings, the area replacement ratio typically varies between 15% and 25%. The net distributed load approach results in a reduction in shear and moment demand on the strip footings. The reduction in shear and moment may be quantified in terms of a reduction factor R_d, that depends on pier spacing and stiffness ratio. This reduction factor may be used to compute the maximum shear and bending moment exerted on RAP-supported footings with the following expressions:

$$V_{max} = \frac{w_{net} L}{2} \left[R_d\right] \quad (9)$$

$$M_{max} = \frac{w_{net} L^2}{8} \left[R_d\right] \quad (10)$$

$$R_d = \left[1 - \frac{(s-d)B}{R_s A_g + A_s}\right] \quad (11)$$

where

d = RAP diameter

A_S = area of matrix soil beneath the strip footing and between the RAP elements.

CONCLUSIONS

Strip footings supported by Rammed Aggregate Pier soil reinforcing elements may be designed by taking into account support contribution from the reinforced soil between the piers. The approach introduces shear and moment reduction factors depending on the pier spacing and stiffness ratio to provide a more efficient design for steel reinforcement and footing thickness than designing the strip footing as a grade beam spanning between the piers.

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