ALTERNATE DESIGN PROCEDURE FOR SLABS ON STABLE SOILS

By

BRIAN M. JUEDES

Authorized reprint from: July 2012 issue of the PTI Journal

ALTERNATE DESIGN PROCEDURE FOR SLABS ON STABLE SOILS

by Brian M. Juedes

Chapter 2.0 of the PTI Design Manual, *third edition, outlines a recommended design procedure for slabs on stable soils. In essence, the procedure simply requires a minimum prestress force of 0.05A after all losses, including the effects of subgrade friction. There is no provision for allowable soil bearing pressure, soil stiffness, or perimeter load. There are no moment, shear, or stiffness requirements for the slab. This paper presents an alternate design procedure for a uniform thickness slab on stable soil. The procedure accounts for allowable soil bearing pressure; soil stiffness and perimeter load; and calculates the design shear, moment, and deflection.*

KEYWORDS

Allowable soil bearing pressure; anchors; eccentricity; ground-supported; post-tensioned slabs; soil stiffness; stable soils; uniform thickness slabs.

INTRODUCTION

The vast majority of the PTI *Design of Post-Tensioned Slabs-on-Ground*, third edition, is written for expansive soils. There are very brief sections on compressible soils and stable soils. Chapter 2.0 provides some general information and a recommended design procedure for slabs on stable soils.

The general information references the BRAB Report[1] No. 33. The report established four basic slab types likely to be encountered. The slab types are designated as:

- Type I: Unreinforced;
- Type II: Lightly reinforced against shrinkage and temperature cracking;
- Type III: Reinforced and stiffened; and
- Type IV: Structural (not directly supported on ground).

Slabs in Type I and Type II categories are usually built on stable soils.

The recommended design procedure for BRAB Type I and Type II slabs is intended to provide a minimum prestress force of $0.05A$ after all losses, including the effects of subgrade friction. The tendon spacing (in feet) required to provide the minimum prestress force at the plan center of Type II uniform thickness slabs with a unit concrete density of 150 lb/cf may be calculated from the following formula

$$\text{Tendon Spacing} = \frac{F_e}{\text{t}(0.6 + 0.003125\ \text{L}) \times 1000}$$

where F_e is effective prestress force per tendon, kips; t is slab thickness, in.; and L is slab length, ft.

TYPICAL EDGE CONDITION

The typical edge condition of a uniform thickness slab with a thickened edge is depicted in Fig. 1. The thickened edge is provided for cover of the tendon anchor and to provide some embedment below the finished grade. The thickened edge is not critical to the design of the slab, as outlined in this paper.

There are two items shown in Fig. 1 that are critical to the design of the slab. First, the perimeter load is applied at the edge of the slab. Consequently, the resultant of the soil bearing pressure gradient is not coincident to the perimeter load. The result is that the perimeter load creates a bending moment in the slab. Second, the tendon anchors are set to provide minimum cover to the top side of the anchor. The eccentricity of the tendon anchor to the slab centroid creates a bending moment in the slab.

BEAM ON ELASTIC FOUNDATION

The equations for a beam on an elastic foundation are readily available in advanced mechanics textbooks and provide a good model for a slab on stable soils. The Winkler foundation model is used in the following listed equations. For a semi-infinite beam with a concentrated vertical load and moment at the end of the beam, as depicted in Fig. 2, the shear, moment, and deflection are given by

$$V = -P_o C_{\beta x} + 2\beta M_o B_{\beta x} \quad \text{(plf)}$$

$$M = \frac{-P_o B_{\beta x}}{x^{\beta}} - M_o A_{\beta x} \quad \text{(lb.-in./ft)}$$

$$\Delta = \frac{2\beta P_o}{k} D_{\beta x} + \frac{2\beta^2 M_o}{k} C_{\beta x} \quad \text{(in.)}$$

where P_o is perimeter load, plf; M_o is end moment, lb-in./ft; k is $k_o b$ psi/ft; k_o is modulus of subgrade, pci; b is unit slab width, 12 in.; β is $(k/4EI)^{1/4}$; E is modulus of elasticity, psi; I is moment of inertia for unit slab width, in ^{4}/ft; = $1/12(12)(t)^3$; = t^3; t is slab thickness, in.

$$A_{\beta x} = e^{-\beta x}(\cos\beta x + \sin\beta x)$$

$$B_{\beta x} = e^{-\beta x}\sin\beta x$$

$$C_{\beta x} = e^{-\beta x}(\cos\beta x - \sin\beta x)$$

$$D_{\beta x} = e^{-\beta x}\cos\beta x$$

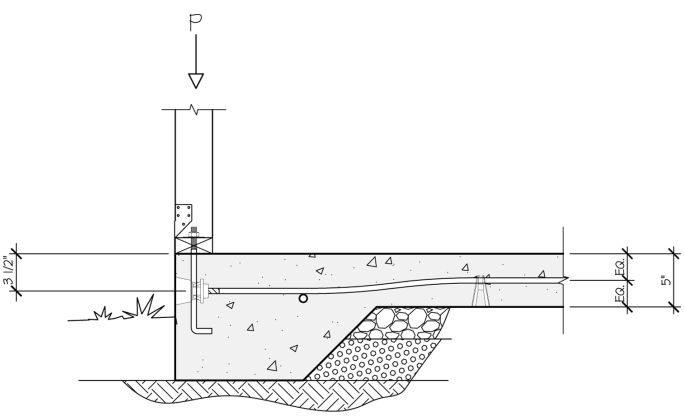

Fig. 1—Uniform thickness slab with thickened edge and perimeter load.

For design purposes, the shear, moment, and deflection equations may be simplified by looking at the boundary conditions.

The maximum deflection occurs at $x = 0$, $C_{\beta X} = 1$, and $D_{\beta X} = 1$.

Therefore

$$\Delta_{MAX} = \frac{2\beta P_o}{k} + \frac{2\beta^2 M_o}{k}$$

$$\Delta_{MAX} = \frac{2\beta}{k} + (P_o + \beta M_o)$$

To check soil bearing, the maximum soil bearing pressure is needed.

$$fbrg_{MAX} = k_o \Delta_{MAX}$$

The maximum moment occurs at $\beta x = \Pi/4$, $\beta_{\beta x} = 0.3224$ if the end moment M_o is zero. If end moment M_o is not zero, the location of maximum moment is not obvious but it will occur between $\beta x = 0$ and $\beta x = \Pi/4$.

The maximum shear occurs at $x = 0$, $C_{\beta x} = 1$.

EXAMPLE PROBLEM

Known:

5 Inch Slab

P_O = 900 plf

M_O = 6422 in-lb/ft based on 28,200 lb per tendon at 4.5 ft on center with a 1 in. anchor eccentricity.

F_{bg} = 1500 psf

k_O = 250 pci

Find: Maximum bending moment and location of maximum moment

Maximum deflection of slab

Maximum soil bearing pressure

$k = k_o b = 250\ (12\text{ in.}) = 3000$ psi/ft.

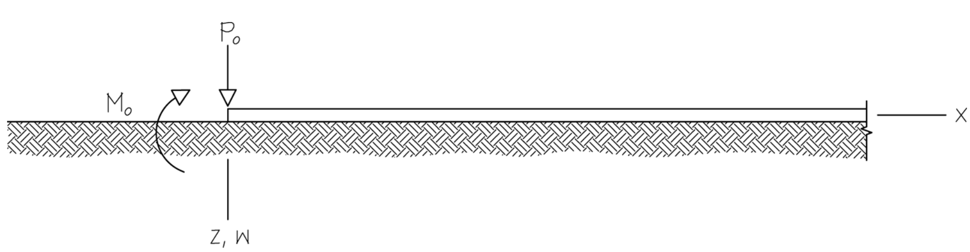

Fig. 2—Semi-infinite beam on a Winkler foundation.

$$\beta = \left[\frac{k}{4EI}\right]^{1/4} = \left[\frac{3000}{4(2{,}850{,}000)(125)}\right]^{1/4} = 0.03809$$

$$M = \frac{P_o}{\beta} B_{\beta x} - M_o A_{\beta x}$$

By solving for M at several βx locations between 0 and $\Pi/4$, the maximum M is found to occur at $\beta x = 0.55$

$$M = \frac{-P_o}{\beta} B_{\beta x} - M_o A_{\beta x}$$

$$M = \frac{-900}{0.3809}(0.3016) - 6422(0.7934)$$

$M = 7126 + 5095$
$M_{max} = 12{,}221$ in.-lb/ft
$\beta x = 0.55$; therefore, $x = 0.55/\beta = 0.55/0.03809 = 14.4$ in.
$\Delta_{MAX} = 2\beta/k(P_o + \beta M_o)$
$= 2(0.03809)/3000\ (900 + (0.03809)(6422))$
$= 0.0291$ in.

$F_{brgmax} = k_o \Delta_{MAX}$
$= 250(.0291)\ (144$ psi/psf$)$
$= 1046$ psf

CONCLUSION

The design procedure defined in this paper applies for any slab (post-tensioned, conventionally reinforced, or unreinforced) on stable soil with a perimeter load and/or an applied end moment. Stable soil is defined as low expansive as determined by the geotechnical engineer, noncompressible, and noncollapsible.

The procedure accounts for allowable soil bearing pressure, soil stiffness, and perimeter load, and calculates the design shear, moment, and deflection. The designer may use the shear, moment, and deflection to design a uniform thickness slab. The resulting soil bearing pressure may also be checked against the allowable soil bearing pressure.

Please refer to p. 67 for the author's bio.