

Rupture Depth of an unreinforced concrete slab on grade?

In the development of standards for the aluminum patio enclosure design industry, this question has been frequently asked. Given an uplifting force at the outboard perimeter edge of an unreinforced concrete slab on grade as shown in Figure 1 we inquire at what distance from the uplifting force is the concrete slab likely to fail (rupture)?

f'_c = compressive strength of concrete in psi; and,
 S_m = section modulus of member considered

since the least concrete strength permitted by code is 2,500 psi

$f'_c := 2500 \cdot \text{psi}$; AND $\phi := 0.55$ (ACI 318-05 provision 9.3.5)

ACI 318-05 Equation 22-2: Design of cross sections subject to flexure shall be based on:

$$\phi \cdot M_n \geq M_u \text{ (ACI 318-05 Equation 22-1)}$$

$$M_n := \phi \cdot 5 \cdot \sqrt{f'_c} \cdot S_m \text{ (ACI 318-05 Equation 22-2) AND;}$$

2007 Florida Building Code (Building) provision 1605.3.2 Alternative basic load combinations reads: "For load combinations that include the counteracting effects of dead and wind loads, only two-thirds of the minimum dead load likely to be in place during a design wind event shall be used"

Expressed as: Windload = .667 x Concrete Deadload

Note: this equation and analysis does not include nor does it consider the deadload of the structure bearing on the foundation.

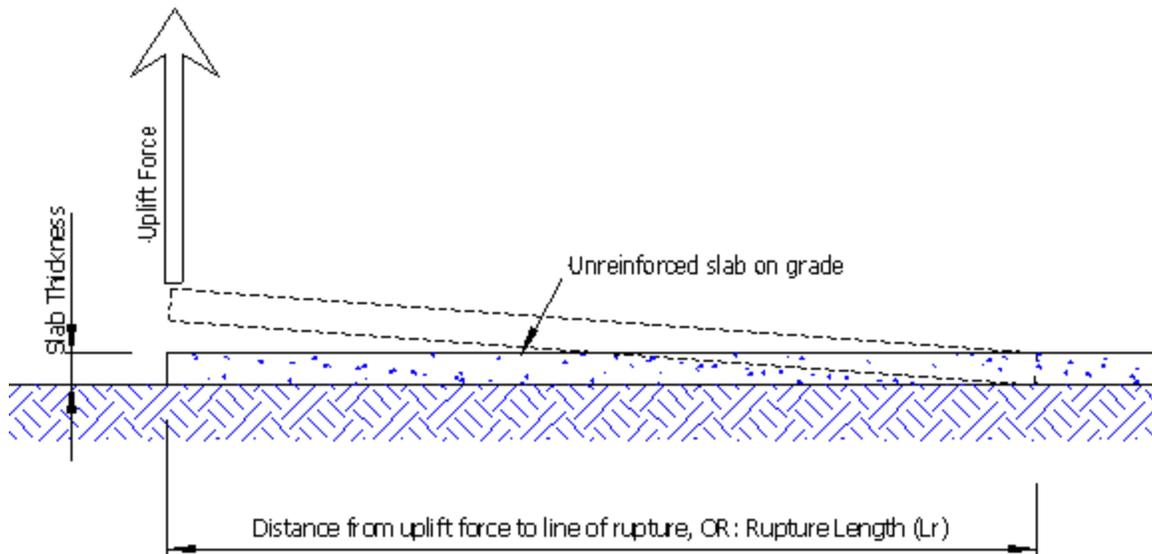


Figure 1: Slab on grade subjected to an uplift force due to wind load on a structure

Fracture Location on a Slab

Since the force uplifting the concrete must overcome the concrete mass, or, dead load of the concrete, we must know the Rupture location from the point of uplift (Length) and slab thickness to compute the uplift force resistance capacity of the concrete.

The slab will be treated as a cantilever beam, one end (inboard) fixed, the other end (outboard) free. Hence, the applied bending moment at the point of rupture, or Rupture Depth will be expressed by the equation:

$$M_b = \frac{1}{2} \cdot \omega_D \cdot L_r^2 \quad (1)$$

where M_b is the applied bending moment, ω_D is the unit mass or weight of the concrete slab (beam) and L_r is the Rupture Length. The allowable bending moment for this section of concrete is expressed by the following equation:

$$M_a = F_b \cdot S_m \quad (2)$$

where, M_a is the allowable bending moment, F_b is the concrete's modulus of rupture, and S_m is the section modulus for the concrete strip (beam) as expressed by the equations:

$$F_b := \phi \cdot 5 \cdot \sqrt{f'_c} \quad (3) \quad \text{ACI 318-05 Equation 22-2}$$

ACI 318-05 provision 22.4.8 requires that the bottom 2" of depth be ignored, thus, for the purpose of calculating the section modulus S_m , $h = 1\frac{1}{2}$ ", not $3\frac{1}{2}$ ":

$$h := 1.5 \cdot \text{in}$$

$$S_m = \frac{1}{6} \cdot A_g \cdot h \quad (4)$$

$$A_g = b \cdot t \quad (5)$$

$$\omega_D = \gamma_c \cdot A_g \quad (6)$$

γ_c is the weight density of the concrete slab.

Equation expressions 1 and 2 and solving for L_r we obtain the following expression:

$$L_r = \sqrt{\frac{2 \cdot M_a}{\omega_D}}$$

Example Problem**Geometry**

Slab width: $b := 12 \cdot \text{in}$

Slab Thickness: $t := 3.5 \cdot \text{in}$

Slab Depth: $h := 1.5 \cdot \text{in}$

Material Properties

Compressive Strength of Concrete: $f'_c := 2.5 \cdot \text{ksi}$

Weight Density of Concrete: $\gamma_c := 145 \cdot \frac{\text{lbf}}{\text{ft}^3}$

Solution

Gross (Net) Area: $A_g := b \cdot t$

Section Modulus: $S_m := \frac{1}{6} \cdot A_g \cdot h$

Dead load due to self-weight: $\omega_D := \gamma_c \cdot A_g$

Allowable bending stress of concrete: $F_b := \phi \cdot 5 \cdot \sqrt{f'_c} \cdot \text{psi}^{0.5}$

Allowable bending moment for concrete: $M_a := F_b \cdot S_m$

Since at Rupture Length ("L_r") $M_a = M_b$, then: $L_r := \sqrt{\frac{2 \cdot M_a}{\omega_D}} \quad L_r = 28.624 \text{ in}$

$$\omega_D = 42.292 \cdot \frac{\text{lbf}}{\text{ft}} \quad DL_{\text{concrete}} := L_r \cdot \omega_D = 100.878 \text{ lbf}$$

Therefore, the uplift capacity per foot of concrete along outboard edge is

$$\text{Uplift}_{\text{Capacity}} := DL_{\text{concrete}} \cdot .667 = 67.286 \text{ lbf}$$