Wind Loads

Velocity pressure at height z

$q_z = 0.00256\ K_z K_{zt} K_d V^2$ (lb/ft^2)

where

K_d = wind directionality factor = 0.85 for most structures

K_z = velocity pressure exposure coefficient

K_{zt} = topographic factor = 1.0 for flat ground

V = basic wind speed (mph)

Velocity Pressure Exposure Coefficient, K_z

Height above Ground (ft)	Exposure		
	B Suburban	C Open Terrain	D Open Water
0–15	0.57	0.85	1.03
20	0.62	0.90	1.08
25	0.66	0.94	1.12

Design of Reinforced Concrete Components (ACI 318-14)

U.S. Customary units

Definitions

a = depth of equivalent rectangular stress block (in.)

A_g = gross area of concrete section (in^2)

A_s = area of longitudinal tension reinforcement (in^2)

A_{st} = total area of longitudinal reinforcement (in^2)

A_v = area of shear reinforcement within a distance s (in.)

b = width of compression face of member (in.)

β_1 = ratio of depth of rectangular stress block a to depth to neutral axis c

$f'_c\,(psi)$	β_1	
$2500 \le f'_c \le 4000$	0.85	(a)
$4000 < f'_c < 8000$	$0.85 - \dfrac{0.05(f'_c - 4000)}{1000}$	(b)
$f'_c \ge 8000$	0.65	(c)

c = distance from extreme compression fiber to neutral axis (in.)
d = distance from extreme compression fiber to centroid of longitudinal tension reinforcement (in.)
d_t = distance from extreme compression fiber to extreme tension steel (in.)
E_c = modulus of elasticity (psi)
= $33 w_c^{1.5} \sqrt{f'_c}$
ε_t = net tensile strain in extreme layer of longitudinal tension reinforcement
f'_c = compressive strength of concrete (psi)
f_y = yield strength of steel reinforcement (psi)
M_n = nominal flexural strength at section (in.-lb)
ϕM_n = design flexural strength at section (in.-lb)
M_u = factored moment at section (in.-lb)
P_n = nominal axial compressive load strength of member (lb)
ϕP_n = design axial compressive load strength of member (lb)
P_u = factored axial force: to be taken as positive for compression and negative for tension (lb)
ρ_g = ratio of total reinforcement area to cross-sectional area of column = A_{st}/A_g
s = center to center spacing of longitudinal shear or torsional reinforcement (in.)
V_c = nominal shear strength provided by concrete (lb)
V_n = nominal shear strength at section (lb)
ϕV_n = design shear strength at section (lb)
V_s = nominal shear strength provided by reinforcement (lb)
V_u = factored shear force at section (lb)

Resistance Factors, ϕ

Tension-controlled sections ($\varepsilon_t \geq 0.005$):	$\phi = 0.9$
Compression-controlled sections ($\varepsilon_t \leq 0.002$):	
Members with tied reinforcement	$\phi = 0.65$
Transition sections ($0.002 < \varepsilon_t < 0.005$):	
Members with tied reinforcement	$\phi = 0.48 + 83\varepsilon_t$
Shear and torsion	$\phi = 0.75$
Bearing on concrete	$\phi = 0.65$

Beams—Flexure

$\phi M_n \geq M_u$

For All Beams

Net tensile strain: $a = \beta_1 c$

$$\varepsilon_t = \frac{0.003\left(d_t - c\right)}{c} = \frac{0.003\left(\beta_1 d_t - a\right)}{a}$$

Singly-Reinforced Beams

$$a = \frac{A_s f_y}{0.85 f'_c b}$$

$$M_n = 0.85 f'_c a b\left(d - \frac{a}{2}\right) = A_s f_y\left(d - \frac{a}{2}\right)$$

Beams—Shear

$$\phi V_n \geq V_u$$

Nominal shear strength:

$$V_n = V_c + V_s$$

$$V_c = 2\lambda\sqrt{f_c'}\,b_w d$$

where

λ = 1.0 for NWC

λ = 0.75 for lightweight concrete

$$V_s = \frac{A_v f_y d}{s} \left(\text{may not exceed } 8\, b_w\, d\sqrt{f_c'}\right)$$

Required and maximum-permitted stirrup spacing s

$V_u \leq \dfrac{\phi V_c}{2}$: No stirrups required

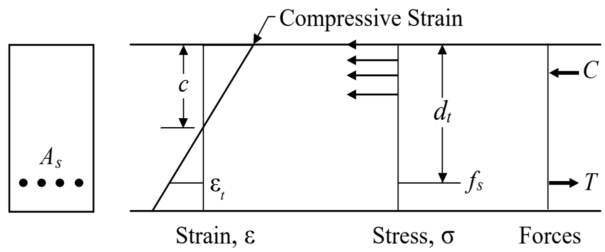
$V_u > \dfrac{\phi V_c}{2}$: Use the following table (A_v given)

ASTM STANDARD REINFORCEMENT BARS

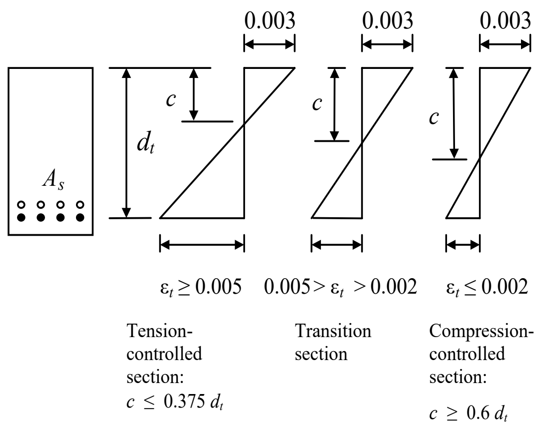
BAR SIZE	DIAMETER, IN.	AREA, IN^2	WEIGHT, LB/FT
#3	0.375	0.11	0.376
#4	0.500	0.20	0.668
#5	0.625	0.31	1.043
#6	0.750	0.44	1.502
#7	0.875	0.60	2.044
#8	1.000	0.79	2.670
#9	1.128	1.00	3.400
#10	1.270	1.27	4.303
#11	1.410	1.56	5.313
#14	1.693	2.25	7.650
#18	2.257	4.00	13.60

Unified Design Provisions

Internal Stress, Strain, and Forces due to Positive Moment Loading



Strain Conditions



<table>
<tr><td></td><td>$\frac{\phi V_c}{2} < V_u \le \phi V_c$</td><td>$V_u > \phi V_c$</td></tr>
<tr><td>Required spacing</td><td>Smaller of:
$s = \frac{A_v f_y}{50 b_w}$
$s = \frac{A_v \, f_y}{0.75 \, b_w \sqrt{f_c'}}$</td><td>$V_s = \frac{V_u}{\phi} - V_c$
$s = \frac{A_v f_y d}{V_s}$</td></tr>
<tr><td rowspan="2">Maximum permitted spacing</td><td rowspan="2">Smaller of:
$s = \frac{d}{2}$
OR
$s = 24"$</td><td>$V_s \le 4 \, b_w \, d \sqrt{f_c'}$
Smaller of:
$s = \frac{d}{2}$ OR
$s = 24"$</td></tr>
<tr><td>$V_s > 4 \, b_w \, d \sqrt{f_c'}$
Smaller of:
$s = \frac{d}{4}$
$s = 12"$</td></tr>
</table>

Short Columns

Limits for Longitudinal Reinforcements

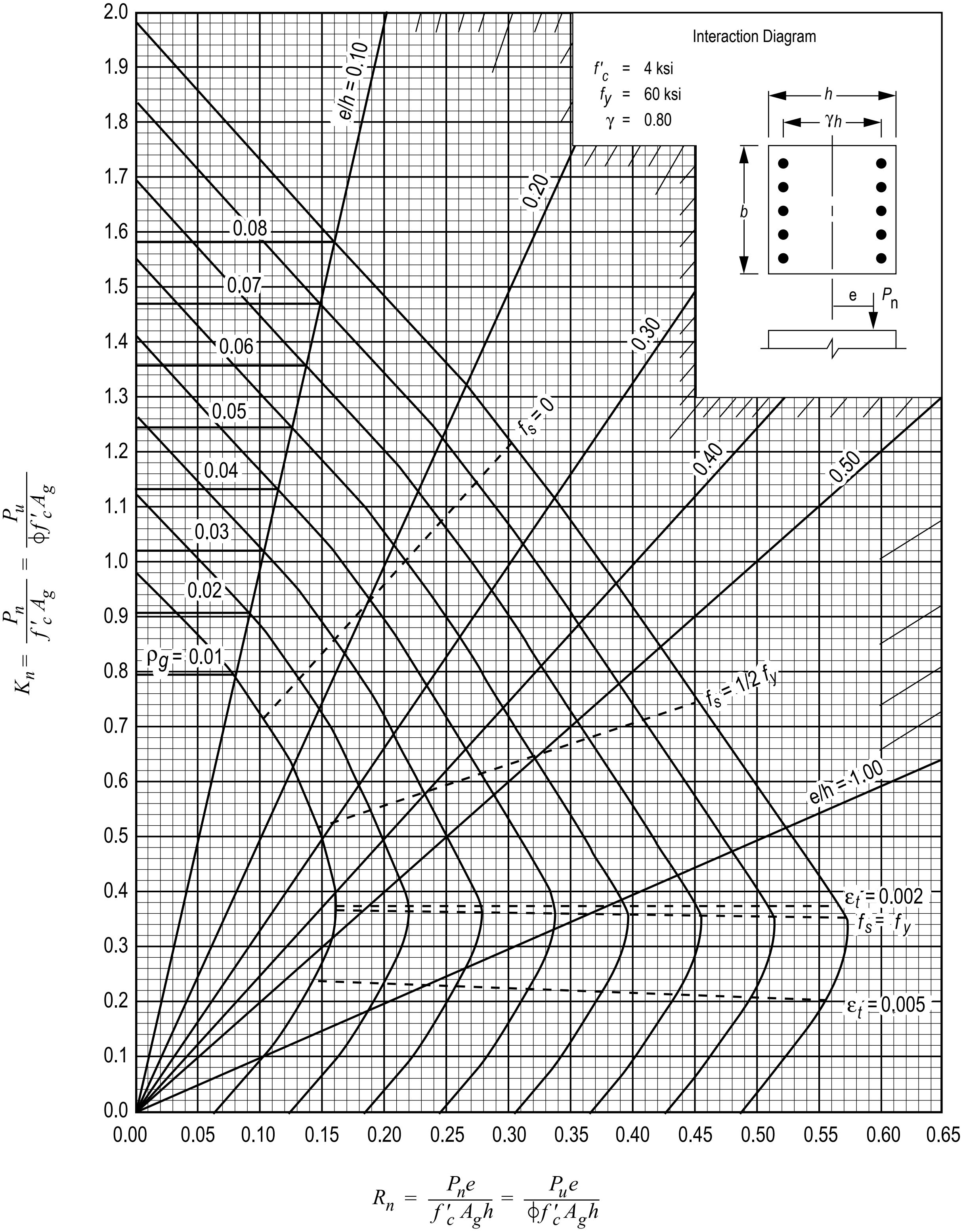
$$\rho_g = \frac{A_{st}}{A_g}$$

$$0.01 \le \rho_g \le 0.08$$

Design Column Strength, Tied Columns

$$\phi P_n = 0.80\phi \, [0.85 \, f_c' \left(A_g - A_{st}\right) + A_{st} \, f_y]$$

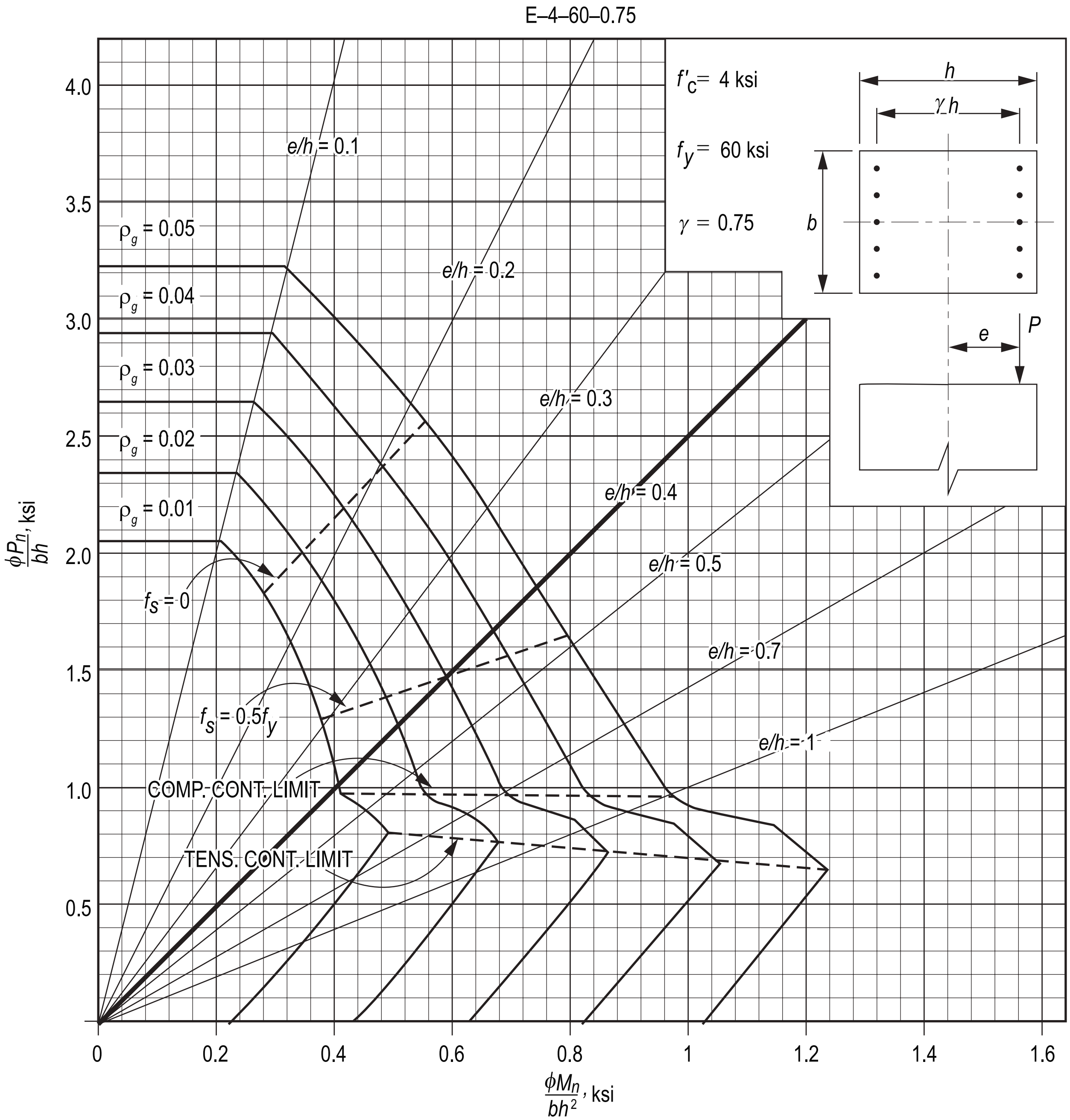
Nominal Column Strength Interaction Diagram for Rectangular Section with Bars on End Faces and $\gamma = 0.80$ (for instructional use only).



GRAPH A.11

Nilson, Arthur H., David Darwin, and Charles W. Dolan, *Design of Concrete Structures*, 13th ed., McGraw-Hill, 2004.

Factored Strength Interaction Diagram for Rectangular Bars on End Faces and $\gamma = 0.75$



Wight, James K., and James G. MacGregor, *Reinforced Concrete*, Mechanics and Design, 6th ed., Pearson, 2012.