ARCH 631. Final Exam Reference Formulas
from Lectures, Examples, and Assignments

$\sum F_x = R_x = 0$	$\sum F_y = R_y = 0$	$\sum M = 0$
$F_x = F\cos\theta$	$F_y = F\sin\theta$	$M = Fd$
$F = \sqrt{F_x^2 + F_y^2}$	$\tan\theta = \frac{F_y}{F_x}$	$tan = \frac{opposite}{adjacent}$
$cos = \frac{adjacent}{hypotenuse}$	$sin = \frac{opposite}{hypotenuse}$	$\delta_T = \alpha(\Delta T)L$
$R_{(case\,1)} = \frac{wl}{2}$	$f = E\varepsilon$	$\varepsilon = \frac{\delta}{L}$
$\delta = \frac{PL}{AE}$	$W = wl$	$w = w' \times tributary\ width$
$V = \int -wdx$	$M = \int Vdx$	area of a rectangle $= b \times h$
area of a triangle $= \frac{b \times h}{2}$	area of a trapezoid $= b \times \frac{(h_1 + h_2)}{2}$	$x = V_A/w$
$M_{max(case\,1)} = \frac{wl^2}{8}$	$f_{b-max} = \frac{M}{S} \le F_b$	$f_{v-max} = \frac{3V}{2A} \le F_v$ for a rectangle
$V_{max(case\,1)} = \frac{wl}{2}$	$S_{req} \ge \frac{M}{F_b}$ $S_{req'd} \ge \frac{M}{F_b}$	$A_{req'd} \ge \frac{3V}{2F_v}$ for a rectangle
$\Delta_{max(case\,1)} = \frac{5wl^4}{384EI}$	$\Delta_{max} \le \Delta_{limit}$	$\Delta_{limit(LL\ or\ TL)}$ in form of $L/number$
1.4D 1.2D + 1.6L + 0.5(L_r or S or R) 1.2D + 1.6(L_r or S or R) + (L or 0.5W) 1.2D + 1.0W + L + 0.5(L_r or S or R) 1.2D + 1.0E + L + 0.2S 0.9D + 1.0W 0.9D + 1.0E	$I_x = \frac{bh^3}{12}$ for a rectangle	$T_v = \frac{wl}{2}$
	$I_y = \frac{b^3h}{12}$ for a rectangle	$T_h = \left(\frac{wL}{2} \cdot \frac{L}{4}\right)\frac{1}{h}$
	$P_{cr} = \frac{\pi^2 EI}{(L_e)^2} = \frac{\pi^2 EA}{\left(L_e/r\right)^2}$	$T = \sqrt{T_v^2 + T_h^2}$
$w = \gamma A$	$f_c = \frac{P}{A} \le F'_c$	$I_x = \sum I_x + \sum A \cdot d_y^2$
$W = mg$	$S = \frac{I}{c}$	$I_y = \sum I_y + \sum A \cdot d_x^2$
$g = 9.81\,m/s^2$	$L_e = KL$	$L_r = L_o(0.25 + \frac{15}{\sqrt{K_{LL}A_T}})$
$R_y = \frac{wL}{2}$	$R_x = \left(\frac{wL}{2} \cdot \frac{L}{4}\right)\frac{1}{h}$	$R = \sqrt{R_x^2 + R_y^2}$

$f_t = \dfrac{P}{A}$	$f_v = \dfrac{P}{A}$	$f_p = \dfrac{R}{A}$
$f_v = \dfrac{VQ}{Ib}$	$Q_y = \bar{x}A = \sum_{i=1}^{n} \bar{x}_i A_i$	$nF_{connector} \geq \dfrac{VQ_{connected\ area}}{I} \cdot p$
$s = x\left[1 + \dfrac{2}{3}\left(\dfrac{y}{x}\right)^2 + \ldots\right]$	$y = {4h(Lx - x^2)}/{L^2}$	$L_{total} = L(1 + {}^{3}\!/_{8}\, {h^2}/{L^2} - {}^{32}\!/_{5}\, {h^4}/{L^4})$

$\sum F_x = 0$	$\sum F_y = 0$	$\sum M = 0$
$V = \int -w dx$	$M = \int V dx$	$M = Fd$
area of a rectangle $= b \times h$	area of a triangle $= \dfrac{b \times h}{2}$	area of a trapezoid $= b \times \dfrac{(h_1 + h_2)}{2}$
fixed base portal frame with assumed inflection points and lateral load: $R_{1x} = R_{2x} = {P}/{2}$ $R_{1y} = -0.45\, {Ph}/{L}$ $R_{2y} = 0.45\, {Ph}/{L}$ $M_1 = M_2 = 0.275Ph$ $M_{joints} = 0.225Ph$	$f_{max} = \dfrac{P}{A} + \dfrac{Mc}{I} = \dfrac{P}{A} + \dfrac{M}{S}$ $w = \gamma A$ simply supported at corners square plate $m_{max} = 0.15w'a^2$ 2. 1.2D + 1.6L	three span beam with integral end supports: $V_{max} = 1.15\, {wL}/{2}$ $M_{max+ends} = {wL^2}/{14}$ $M_{max+interior} = {wL^2}/{16}$ $M_{max-column} = {wL^2}/{16}$ $M_{max\text{-}ends,other\ support} = {wL^2}/{10}$ $M_{max\text{-}interior} = {wL^2}/{11}$
$M = Td$	slab depth = L/number or ℓ_n/number	

$\ell_n = \ell - {}^{1}\!/_{2}$ support 1 width $- {}^{1}\!/_{2}$ support 2 width	$m = M/\text{strip width}$	$M_o = (M_T) = \dfrac{w_u \ell_2 \ell_n^2}{8}$
flat slab, interior bay, COLUMN strip: $M_{negative} = (0.75 \cdot 0.65 M_T) = 0.49 M_o$ $M_{positive} = (0.60 \cdot 0.35 M_T) = 0.21 M_o$ flat slab, interior bay, MIDDLE strip: $M_{negative} = (0.25 \cdot 0.65 M_T) = 0.16 M_o$ $M_{positive} = (0.40 \cdot 0.35 M_T) = 0.14 M_o$	fully fixed square plate $m_{negative} = 0.0513w'a^2$	$\phi M_n = \phi A_s f_y \left(d - {a}/{2}\right) \quad \phi = 0.9$ *
	$a = \dfrac{A_s f_y}{0.85 f'_c b}$	to determine maximum steel for 0.005 strain $c = 0.375d$, $a = \beta_1 c$
	$M_{max(case\ 1)} = \dfrac{wl^2}{8}$	$R_n = \dfrac{M_n}{bd^2}$ or $\dfrac{M_u}{\phi bd^2}$
	$\rho = \dfrac{A_s}{bd}$	$V_{x(case\ 1)} = {wl}/{2} - wx$

beam: $A_{s-min} = \dfrac{3\sqrt{f'_c}}{f_y}(b_w d)$ not less than $\dfrac{200}{f_y}(b_w d)$	$\phi V_c = \phi 2\lambda \sqrt{f'_c} b_w d \quad \lambda = 1.0$ normal weight
$\phi V_c \geq V_u > {\phi V_c}/{2}$: $s_{required}$ = smaller of $\dfrac{A_v f_{yt}}{50 b_w}$ and $\dfrac{A_v f_{yt}}{0.75\sqrt{f'_c}\, b_w}$	$V_u \leq \phi V_c + \phi V_s \quad \phi = 0.75$

$V_u > \phi V_c$: $s_{required} = \dfrac{\phi A_v f_{yt} d}{V_u - \phi V_c}$ or $\dfrac{\phi A_v f_{yt} d}{\phi V_s}$	$P = f \cdot A$	sphere: $T = p_r\, {R}/{2}$
$N_\phi = \dfrac{Rw}{1 + \cos\phi} = \dfrac{W}{2\pi R \sin^2\phi}$	$T = N_\phi \cos\phi a$	cylinder: $T = p_r R$

$N_\theta = Rw\left(-\frac{1}{1+\cos\phi}+\cos\phi\right)$	$a = R\sin\phi$	$w = \gamma t$	$f = T/t$
single overhang at 0.292L: $M = 0.043wL^2$	double overhangs at 0.21L: $M = 0.021wL^2$	$f_\phi = N_\phi/t$	$f_\theta = N_\theta/t$
$P_o = 0.85 f_c'(A_g - A_{st}) + f_y A_{st}$	$L_{LL} = L_o(0.25+\frac{15}{\sqrt{K_{LL}A_T}})$	slabs: $A_{s\text{-}min} = 0.002bt$ (40 or 50 grade) $A_{s\text{-}min} = 0.0018bt$ (60 grade)	
tied: $\phi_c P_n = \phi_c(0.8P_o)$ $\phi_c = 0.65$	$V_{u2} = w_u(\text{tributary area} - b_1 \times b_2)$	$V_{u2} \le \phi\left(2+\frac{4}{\beta_c}\right)\lambda\sqrt{f_c'}b_o d \le \phi 4\lambda\sqrt{f_c'}b_o d$	
spiral: $\phi_c P_n = \phi_c(0.85P_o)$ $\phi_c = 0.75$	$b_E = min(\frac{\ell_n}{4}$, $b_w + 16t$, or center-center spacing)	$b_o = 2(b_1)+2(b_2)$	
$E_c = 57{,}000\sqrt{f_c'}$ normal weight			

$w = w' \times tributary\ width$	$W = w \times tributary\ height$	$R = W/$#parallel support walls
$M = Fd$	$V = ZICW/R_W$	$C = \frac{1.25S}{T^{2/3}}$
$M_{max(simply\ supported)} = \frac{wl^2}{8}$	$f_v = \frac{P}{A}$	$A_{circle} = \pi r^2 = \pi D^2/4$
$f_v = \frac{P}{L(0.707t)}$	$f_v = \frac{P}{2A}$	$R_u \le \phi R_n$
shear: $R_u \le \phi r_n n$	bearing: $R_u \le \phi r_n tn$	capacity = min { all ϕR_n 's}
$f_p = \frac{P}{td}$	$S = \frac{bh^2}{6}$	$f_{b-max} = \frac{M}{S} \le F_b$
$M_{max(cantilever)} = \frac{wl^2}{2}$	$M_{max(3\ spans)} = 0.1wl^2$	$V_{max(simply\ supported)} = \frac{wl}{2}$
$v_{wall} = \frac{V}{L_{wall}}$	$v_{diaphragm} = \frac{V}{L_{in\ diaphragm}}$	$V = C_s W$
$S_{MS} = F_a S_S$	$C_s = \frac{S_{DS}}{(R/I)}$ not less than $\frac{S_{D1}}{T(R/I)}$	$S_{DS} = \frac{2}{3}S_{MS}$
$P \le n \cdot q$	$f_v = \frac{VQ}{Ib}$	$nF \ge \frac{VQ_{connected}}{I}p$
$f_v = \frac{3V}{2A}$	$\phi R_n = \phi F_u A_e$ $\phi = 0.75$	$A_e = A_n U$
$\phi R_n = \phi SL$ $\phi = 0.75$	$\phi R_n = \phi F_y A_g$ $\phi = 0.9$	$F' = C_D C_M C_F \ldots \times F_{tabulated}$

$R_u \le \phi(0.6F_uA_{nv} + U_{bs}F_uA_{nt} \le 0.6F_yA_{gv} + U_{bs}F_uA_{nt}) \quad \phi = 0.75$		$F_{cE} = \dfrac{0.822E'_{min}}{\left(l_e/d\right)^2}$ $E'_{min} = E_{min}(C_M)(C_t)(C_T)(C_i)$
$w = \gamma A$	$\Delta_{max} \le \Delta_{limit}$	
$S_{req} \ge \dfrac{M}{F'_b}$	$\Delta_{max(\,simply\ supported)} = \dfrac{5wl^4}{384EI}$	$F_c^* \cong F_cC_D$
$\left[\dfrac{f_c}{F'_c}\right]^2 + \dfrac{f_{bx}}{F'_{bx}\left[1 - f_c/F_{cEx}\right]} \le 1.0$	$SF = \dfrac{M_{resist}}{M_{overturning}} \ge 1.5$	$F'_c = F_c^*C_p$ $P_a = F'_cA$

$M_{max(simply\ supported)} = \dfrac{wl^2}{8}$	$\Delta_{max} \le \Delta_{limit}$	$M_u \le \phi M_n$ or $M_a \le M_n/\Omega$
1.4D 1.2D + 1.6L + 0.5(L_r *or S or R*) 1.2D + 1.6(L_r *or S or R*) + (L or 0.5W) 1.2D + 1.0W + L + 0.5(L_r *or S or R*) 1.2D + 1.0E + L + 0.2S 0.9D + 1.0W 0.9D + 1.0E	$P_u \le \phi P_n$ or $P_a \le P_n/\Omega$	$r = \sqrt{\dfrac{db^3}{12(bd)}} = \dfrac{b}{\sqrt{12}}$
	$I_{req'd} = \dfrac{(\Delta_{formula} \cdot I)}{\Delta_{limit\,value}}$	$f_v = \dfrac{V}{A_{nv}} \le F_v$
$w = w' \times tributary\ width$	$F_{vm} = \dfrac{1}{2}\left[\left(4 - 1.75\left(\dfrac{M}{Vd}\right)\right)\sqrt{f'_m}\right] + 0.25\dfrac{P}{A_n}$ where M/Vd is positive and cannot exceed 1.0	$F_{vs} = 0.5\left(\dfrac{A_vF_sd}{A_{nv}s}\right)$
$w_{adjusted} = w_{ll-have}\left(\dfrac{L/360}{L/400}\right)^{table}_{need}$	$F_{v-max} = 3\sqrt{f'_m}$ for $M/Vd \le 0.25$ $F_{v-max} = 2\sqrt{f'_m}$ for $M/Vd \ge 1.0$	$F_v = F_{vm} + F_{vs}$
$KL_x = \dfrac{KL_y}{(r_x/r_y)}$		$A_{nv} = bh - A_s$
$P_a = [0.25f'_mA_n + 0.65A_{st}F_s]\left[1 - \left(\dfrac{h}{140r}\right)^2\right]$ for h/r ≤ 99 (reinforced)		$\dfrac{P}{A} \le q_a$
$P_a = [0.25f'_mA_n + 0.65A_{st}F_s]\left(\dfrac{70r}{h}\right)^2$ for h/r > 99 (reinforced)		$q_u = \dfrac{P_u}{A}$
$V_{u1} = BL'q_u$	$\phi V_{n1} = \phi 2\lambda\sqrt{f'_c}Bd \quad \phi = 0.75$	$L_m = \dfrac{B}{2} - \dfrac{\bullet}{2}$ where • is smaller dimension of column
$V_{u2} = P_u - q_u(c+d)(b+d)$	$b_o = 2(c+d) + 2(b+d)$	$M_u = q_u\dfrac{BL_m^2}{2}$
$\phi V_{n2} = \phi\left(2 + \dfrac{4}{\beta}\right)\lambda\sqrt{f'_c}b_od \le \phi 4\lambda\sqrt{f'_c}b_od \quad \phi = 0.75$	$P = \dfrac{\gamma h^2}{2}$ at h/3	$P_{e1} = \dfrac{\pi^2EI}{(L_{c1})^2}$

<table>
<tr><td colspan="2">$\frac{P_r}{P_c} \ge 0.2 : \frac{P_r}{P_c} + \frac{8}{9}\left(\frac{M_{rx}}{M_{cx}} + \frac{M_{cy}}{M_{ry}} \right) \le 1.0$</td><td>$B_1 = \frac{C_m}{1 - \alpha(P_u / P_{e1})} \ge 1.0$</td></tr>
<tr><td colspan="2">$\frac{P_r}{P_c} < 0.2 : \frac{P_r}{2P_c} + \left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}} \right) \le 1.0$</td><td>$C_m = 0.6 - 0.4 \frac{M_1}{M_2}$ where $M_1 < M_2$</td></tr>
<tr><td>$I_{req'd} \ge \frac{\Delta_{toobig}}{\Delta_{limit}} I_{trial}$</td><td>$V_u \le \phi V_n = \phi(0.6 F_{yw}) t_w d \quad \phi = 1.0$</td><td>$M_r = B_1 M_{nt}$</td></tr>
<tr><td>$R_u \le \phi R_n$</td><td>bearing: $R_u \le \phi r_n t n$</td><td>shear: $R_u \le \phi r_n n$</td></tr>
<tr><td>$\phi R_n = \phi(0.6) F_y A_g \quad \phi = 1.0$</td><td>$\phi R_n = \phi(0.6) F_u A_{nv} \quad \phi = 0.75$</td><td>$U_{bs} = 0.5$
when tensile stress is non-uniform</td></tr>
<tr><td colspan="2">$R_u \le \phi(0.6 F_u A_{nv} + U_{bs} F_u A_{nt} \le 0.6 F_y A_{gv} + U_{bs} F_u A_{nt}) \quad \phi = 0.75$</td><td rowspan="3">$\ell$ is the largest of:
$m = \frac{N - 0.95d}{2}$
$n = \frac{B - 0.8b_f}{2}$
$\lambda n'$ where $n' = \frac{\sqrt{db_f}}{4}$ and
$\lambda = \frac{2\sqrt{X}}{(1 + \sqrt{1 - X})} \le 1$</td></tr>
<tr><td colspan="2">$X = \frac{4db_f}{(d + b_f)^2} \cdot \frac{P_u}{\phi_c P_p} = \frac{4db_f}{(d + b_f)^2} \cdot \frac{P_u}{\phi_c (0.85 f'_c) BN} \quad \phi_c = 0.65$</td></tr>
<tr><td>$P_p = 0.85 f'_c A$</td><td>$t_{min} = \ell \sqrt{\frac{2P_u}{0.9 F_y BN}}$</td></tr>
<tr><td>$f_b - f_a \le F_t$</td><td>$f_b = \frac{Mc}{I} = \frac{M}{S}$</td><td>$M = Pe$</td></tr>
<tr><td>$f_a + f_b \le F_b$</td><td>$M \le M_s = A_s F_s (jd) \quad j = 0.909$</td><td>$\frac{f_a}{F_a} + \frac{f_b}{F_b} \le 1$</td></tr>
<tr><td>$f_a \le F_a$</td><td>$F_v = 1.5 \sqrt{f'_m} \le 120\ psi$ unreinforced</td><td>$f_v = \frac{VQ}{I_n b} = \frac{3V}{2A}$ solid rectangle</td></tr>
<tr><td>with $M = Vh, M/Vd = h/d$</td><td>$F_b = 0.45 f'_m$ reinforced</td><td>$F_b = 0.33 f'_m$ unreinforced</td></tr>
<tr><td>$F = \mu N$</td><td>$SF = \frac{M_{resist}}{M_{overturning}} \ge 1.5 - 2$</td><td>$SF = \frac{F_{horizontal-resist}}{F_{sliding}} \ge 1.25 - 2$</td></tr>
</table>