

Introduction to Spread Footing Design Flow Charts

Spread Footing Charts in Bullets:

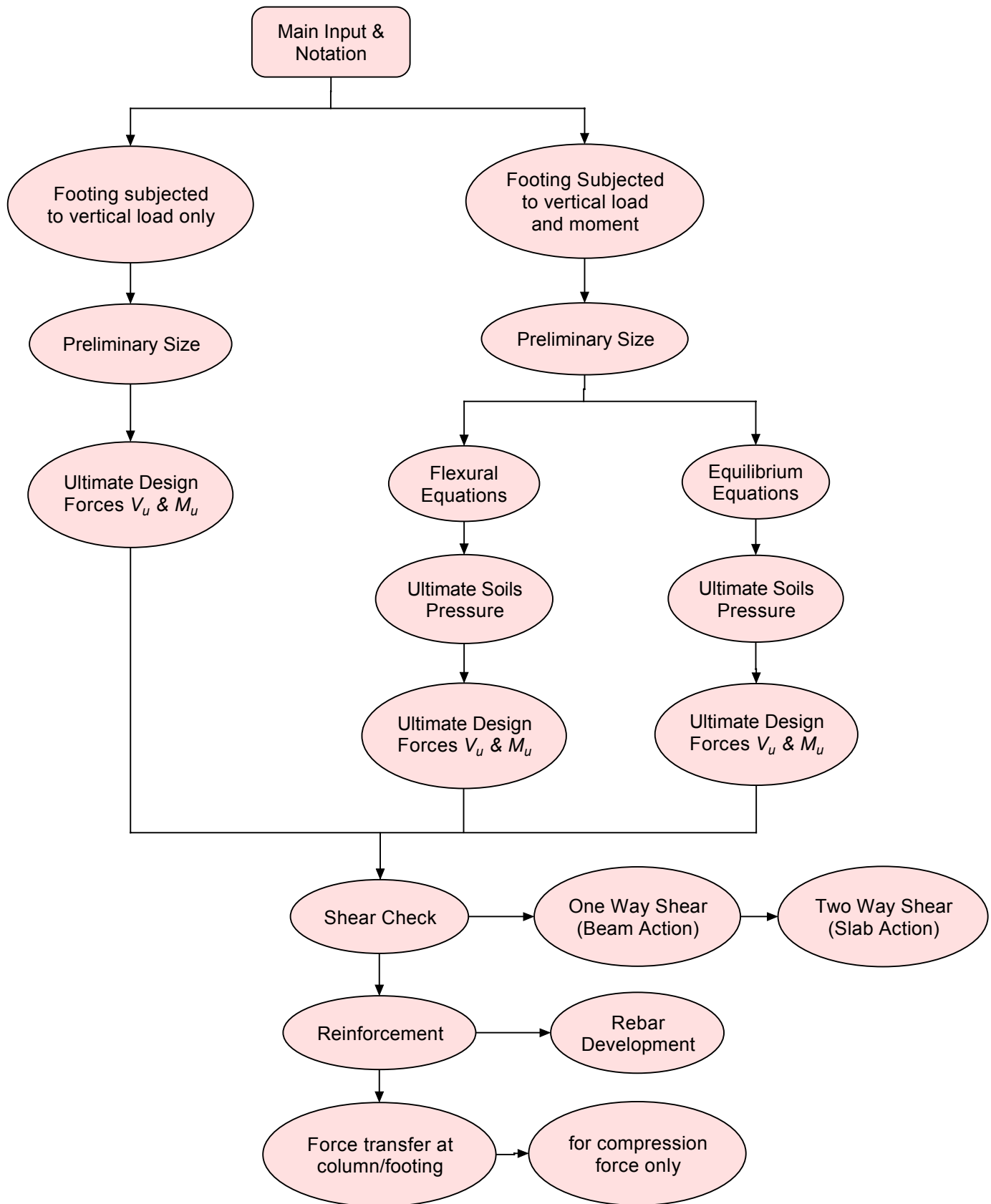
- All code provisions are listed, where applicable, on the charts for quick reference.
- Analysis assume rigid footing condition, resulting in a uniform soil pressure for concentric load, and a triangular or trapezoidal soil pressure for eccentric loading (combined axial and bending)
- Establish preliminary size under service loads, and proportion rectangular footing dimensions, if required, around a rectangular column.
- Calculate in one single equation one-way shear, two-way shear, and design moment, under factored loads, respectively.
- Deal separately with two eccentricity conditions, while $e < L/6$ flexural equations are used, and for $e > L/6$ equilibrium equations are used.
- Drive the nominal shear strength of the concrete for both beam shear (one way) and punching shear (two way, or slab shear). Alternatively, provide reference to the code provisions where shear reinforcement may be used in case of factored shear force exceeded nominal concrete shear strength with restricted footing depth.
- Calculate required flexural reinforcement ratio and compared with the minimum and maximum permitted by code, and provide required tensile reinforcement, and calculate rebar development length.
- Address axial force transfer at the column base (for compression only), and fully detailing the dowels design and development length required into footing and column.
- Include sketches illustrating the subject under investigation.

Include notations sheet explaining in details all symbols used in the charts.

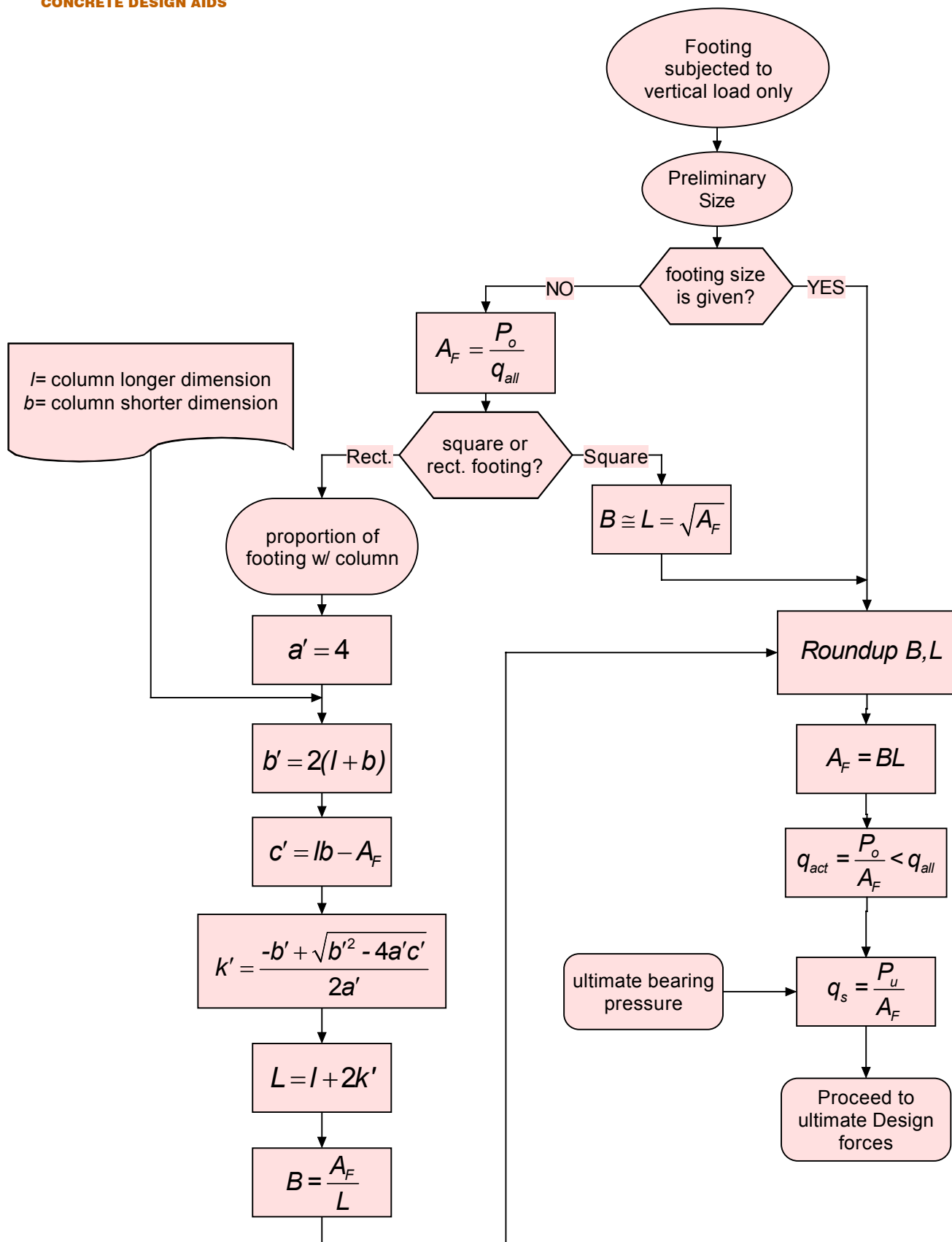
Notations for Spread Footing Design Flow Charts

A_s	=	area of reinforcement.
b	=	column width dimension.
b_o	=	perimeter of critical shear section for footing.
B	=	footing width dimension.
d	=	distance from extreme compression fiber to centroid of tension reinforcement.
d_b	=	nominal diameter of bar.
f'_c	=	specified compressive strength of concrete.
f_y	=	specified tensile strength of reinforcement.
h	=	overall member thickness.
l	=	column length dimension.
l_{ava}	=	available length for bar development.
l_d	=	development length of bar in tension.
l_s	=	compression lap splice length.
l_{db}	=	basic development length of bar in compression.
L	=	footing length dimension.
P_o	=	axial load, service.
P_u	=	axial load, ultimate.
q_{act}	=	actual soil pressure based on service loads condition.
q_{all}	=	allowable soil bearing pressure.
q_s	=	factored actual soil pressure.
R_u	=	coefficient of resistance.
V_u	=	factored shear force at section considered.
V_c	=	nominal shear strength of concrete.
β_c	=	ratio of long side to short side of column dimensions.
ρ	=	ratio of tension reinforcement.
ρ_b	=	ratio of tension reinforcement at balanced strain condition.
ρ_{max}	=	maximum ratio permissible by code.
ρ_{min}	=	minimum ratio permissible by code.
$\rho_{req'd}$	=	required ratio of tension reinforcement.
$\rho_{prov'd}$	=	provided ratio of tension reinforcement.
ϕ	=	strength reduction factor.

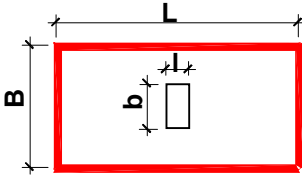
Spread Footing Analysis & Design Main Chart



Preliminary Size of Footing Subjected to Vertical Loads only.



Ultimate Forces for Footing Subjected to Vertical Loads only



Ultimate Design Forces V_u & M_u

finding V_u

one way shear (beam action)

Short Direction

$$V_u = q_s B (0.5L - 0.5l - d)$$

long. Direction

$$V_u = q_s L (0.5B - 0.5b - d)$$

two way shear (slab action)

$$b_o = 2[(l+d) + (b+d)]$$

use w/ V_c calculation

$$V_u = q_s [A_F - (l+d)(b+d)]$$

finding M_u

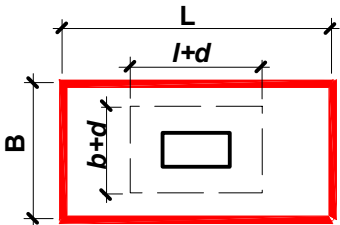
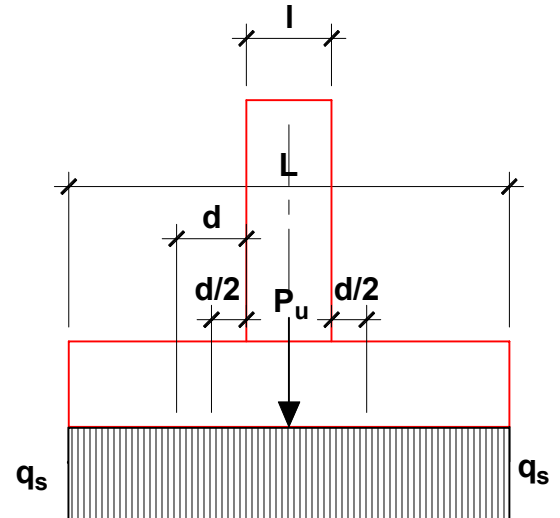
Longitudinal Direction

$$M_u = 0.125 q_s B (L-l)^2$$

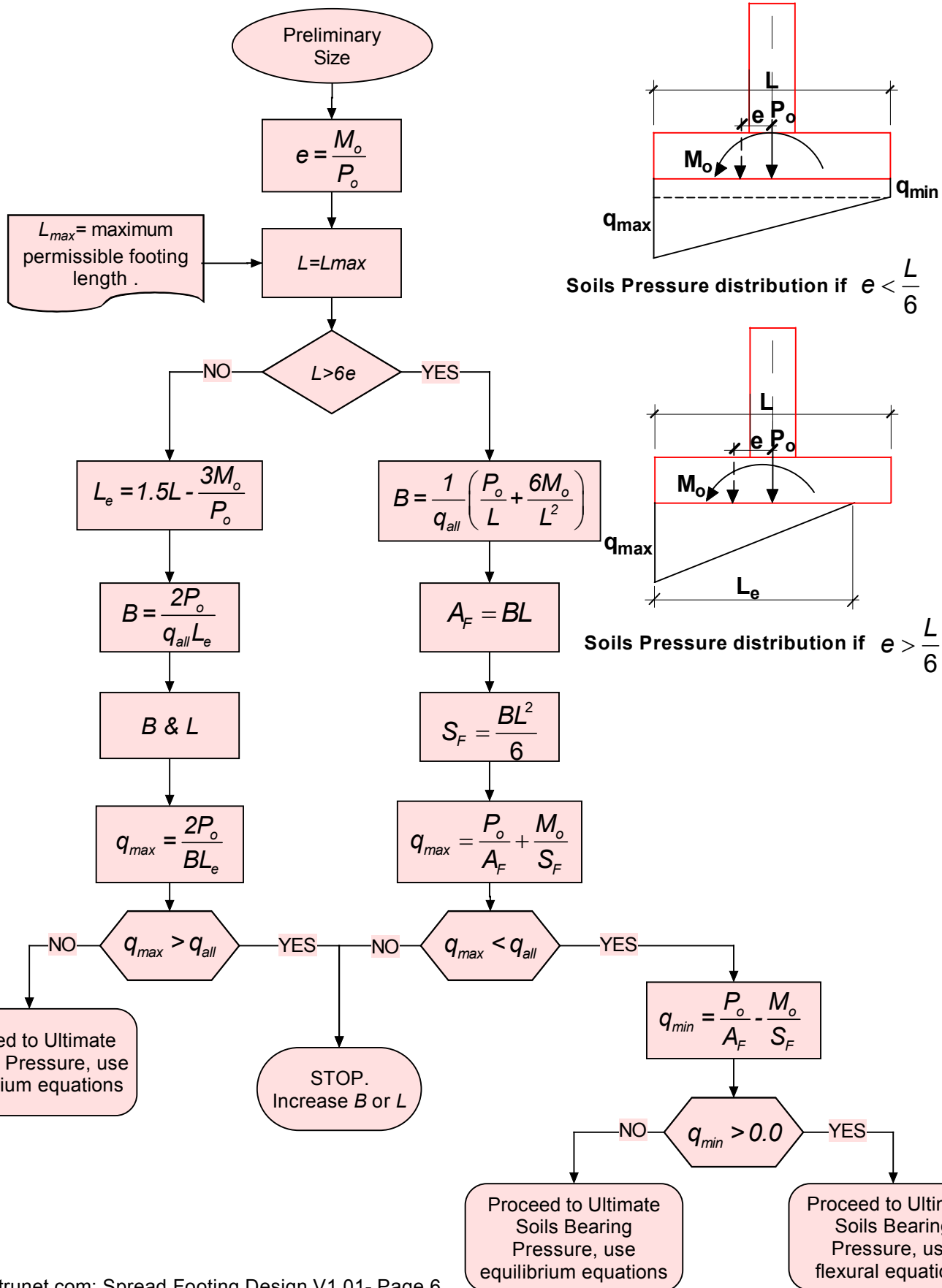
Transverse Direction

$$M_u = 0.125 q_s L (B-b)^2$$

Note: the following footing forces calculations are based on:
 l = column dimension parallel to L
 b = column dimension parallel to B

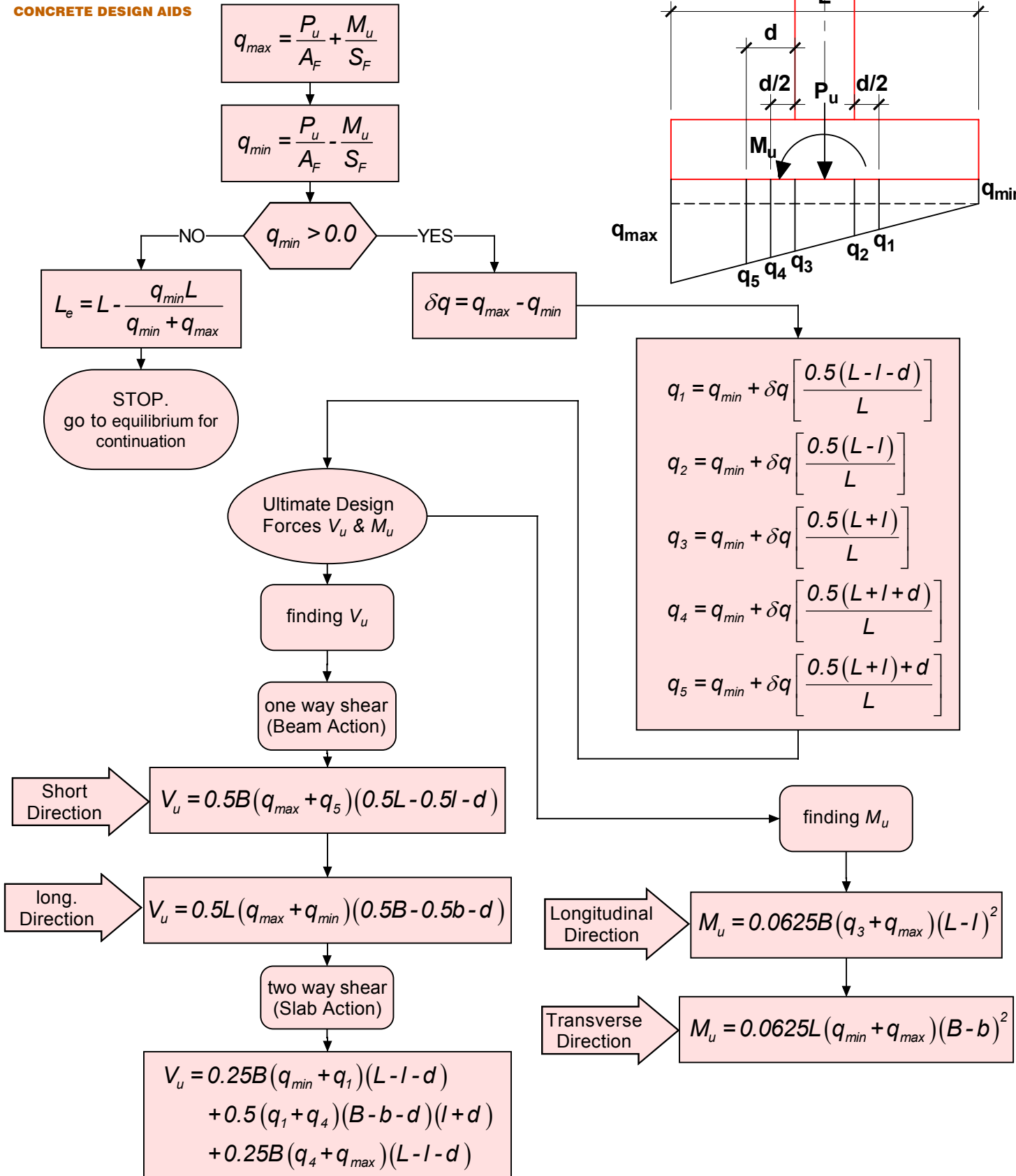
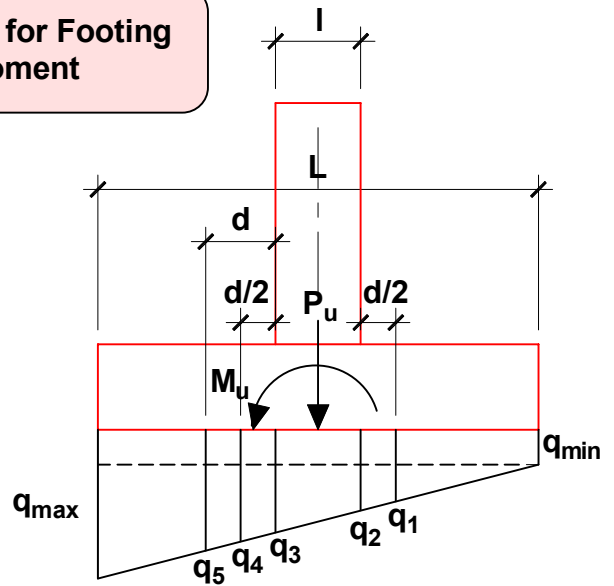


Preliminary Size of Footing Subjected to Vertical Load and Moment



Ultimate Forces with Flexural Equations for Footing Subjected to Vertical Load and Moment

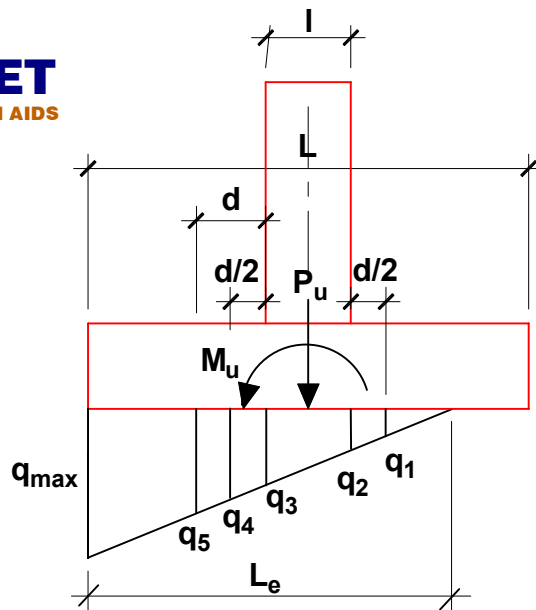
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Ultimate Forces with Equilibrium Equations for Footing Subjected to Vertical Load and Moment

Ultimate Bearing Pressure using Equilibrium Equations

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$$L_e = 1.5L - \frac{3M_u}{P_u}$$

$$q_{max} = \frac{2P_u}{BL_e}$$

$$\begin{aligned} q_1 &= \frac{0.5q_{max}}{L_e}(2L_e - L - l - d) \\ q_2 &= \frac{0.5q_{max}}{L_e}(2L_e - L - l) \\ q_3 &= \frac{0.5q_{max}}{L_e}(2L_e - L + l) \\ q_4 &= \frac{0.5q_{max}}{L_e}(2L_e - L + l + d) \\ q_5 &= \frac{0.5q_{max}}{L_e}(2L_e - L + l + 2d) \end{aligned}$$

Ultimate Design Forces V_u & M_u

one way shear (Beam Action)

Short Direction

$$V_u = 0.5B(q_5 + q_{max})(0.5L - 0.5l - d)$$

long. Direction

$$V_u = 0.5q_{max}L_e(0.5B - 0.5b - d)$$

two way shear (Slab Action)

Longitudinal Direction

$$M_u = 0.0625B(q_3 + q_{max})(L - l)^2$$

Transverse Direction

$$M_u = 0.0625L_e q_{max}(B - b)^2$$

$$L_e > 0.5(L + l + d)$$

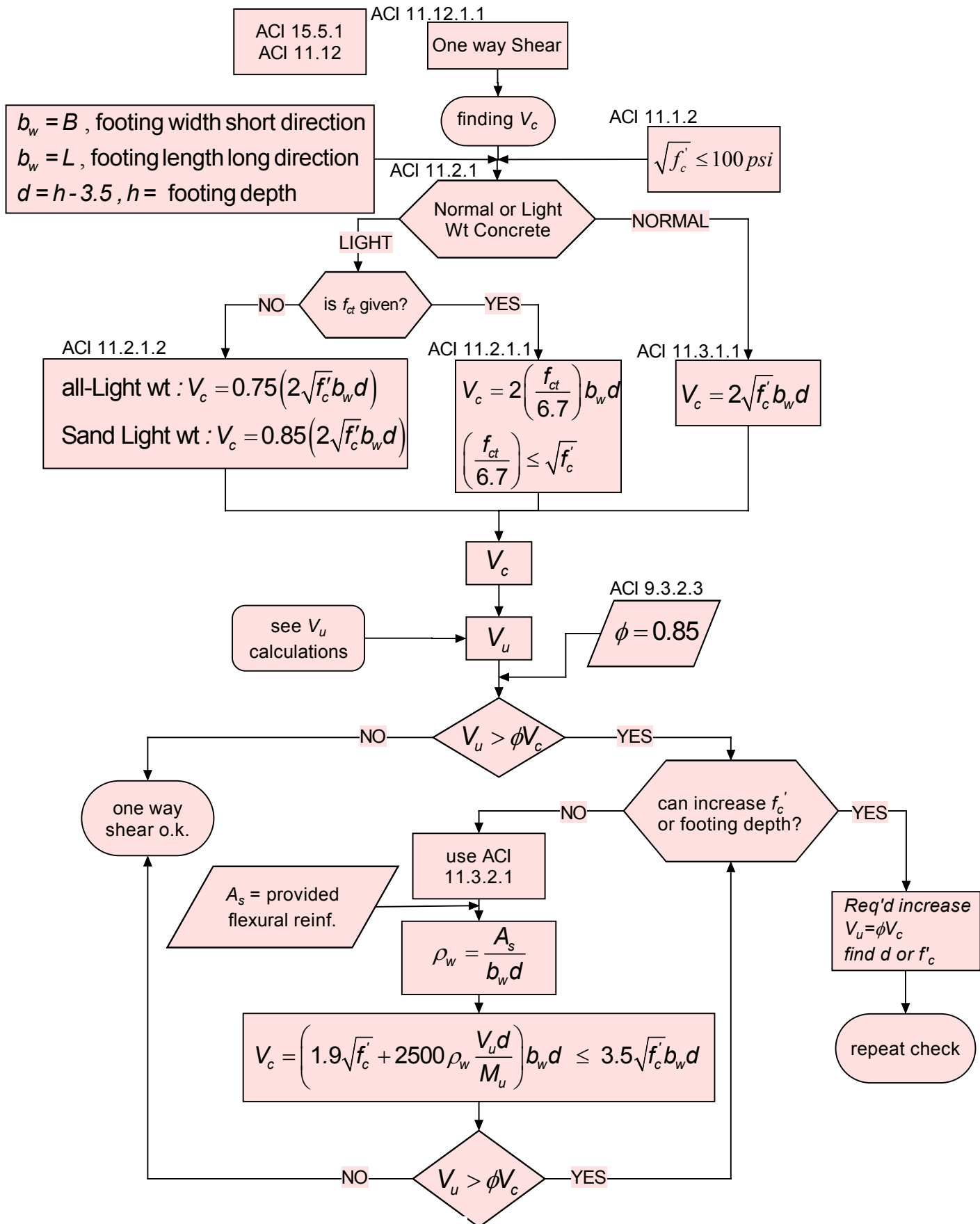
$$L_e > 0.5L + 0.5l$$

STOP.
increase L

$$\begin{aligned} V_u &= 0.25B(q_4 + q_{max})(L - l - d) \\ &+ 0.25q_4(2L_e - L + l + d)(B - b - d) \end{aligned}$$

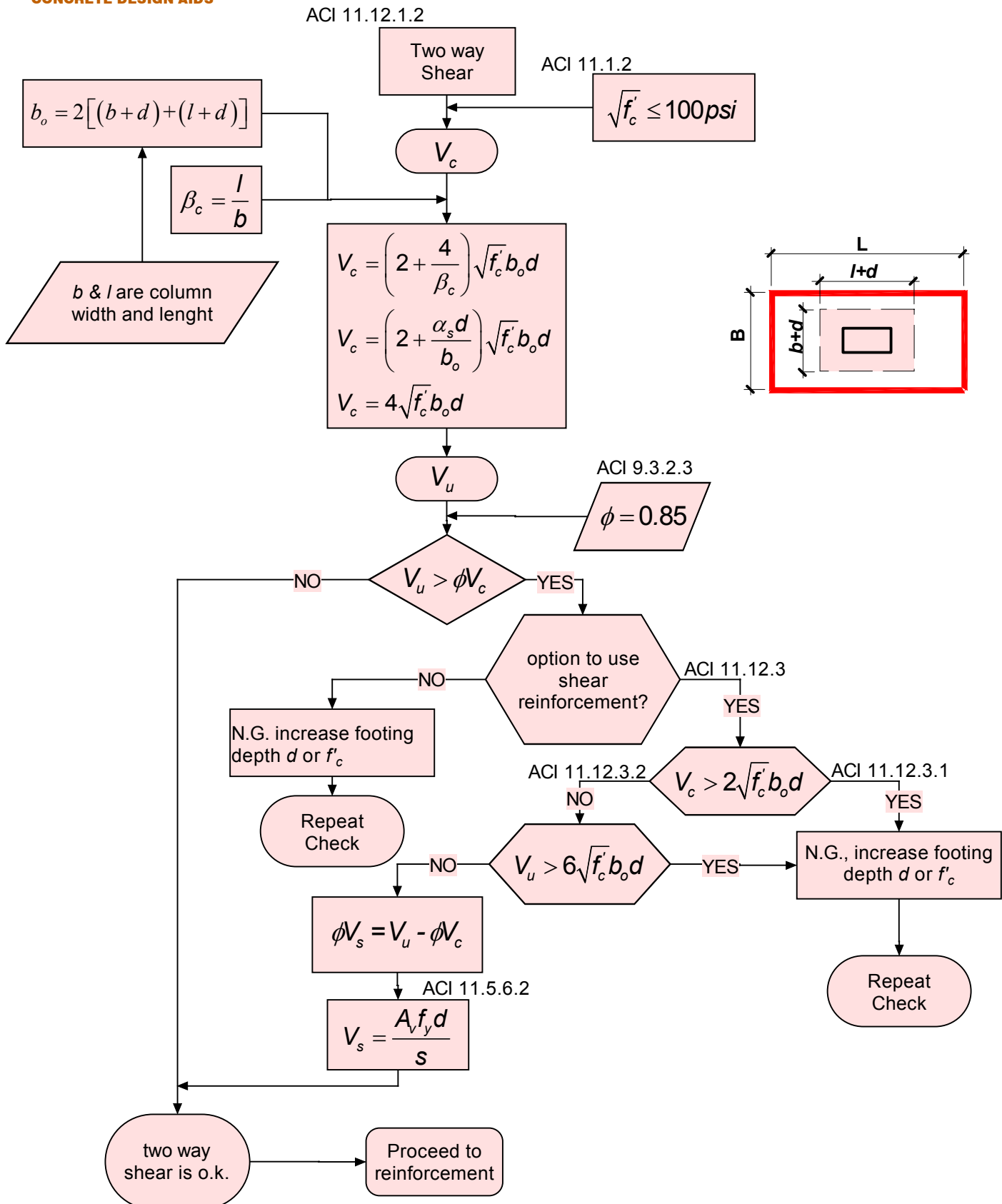
$$\begin{aligned} V_u &= 0.25q_1B(2L_e - L - l - d) \\ &+ 0.5(q_1 + q_4)(B - b - d)(l + d) \\ &+ 0.25B(q_4 + q_{max})(L - l - d) \end{aligned}$$

One-Way Shear Check for Spread Footing



Two-Way Shear Check for Spread Footing

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**Area of Reinforcement
for Spread Footing**

ACI 7.12.2

finding ρ_{min}

$f_y > 60 \text{ ksi} ?$

NO

YES

$$\rho_{min} = 0.0018 \left(\frac{60,000}{f_y} \right)$$

NO

YES

$$\rho_{min} = 0.0018$$

$$\rho_{min} = 0.002$$

ACI 10.3.3

finding ρ_{max}

ACI 10.2.7.3

$f'_c \leq 4000 \text{ psi} ?$

NO

YES

ACI 10.2.7.3

$$\beta_1 = 0.85 - 0.05 \left(\frac{f'_c - 4000}{1000} \right) \geq 0.65$$

$$\beta_1 = 0.85$$

ACI 8.4.3

$$\rho_b = \frac{0.85f'_c}{f_y} \beta_1 \left(\frac{87,000}{87,000 + f_y} \right)$$

ACI 10.3.3

$$\rho_{MAX} = 0.75 \rho_b$$

see M_u
calculations

M_u

ACI 9.3.2.1

$\phi = 0.9$

$$R_u = \frac{M_u}{\phi b d^2}$$

$$\rho_{req'd} = \frac{0.85f'_c}{f_y} \left(1 - \sqrt{1 - \frac{2R_u}{0.85f'_c}} \right)$$

$\rho_{req'd} \geq \rho_{min} ?$

NO

YES

$\rho_{req'd} \leq \rho_{max} ?$

NO

YES

ACI 10.5.2

$$\rho = 1.33 \rho_{req'd}$$

$\rho < \rho_{Min} ?$

NO

YES

$$\rho = 1.33 \rho_{req'd}$$

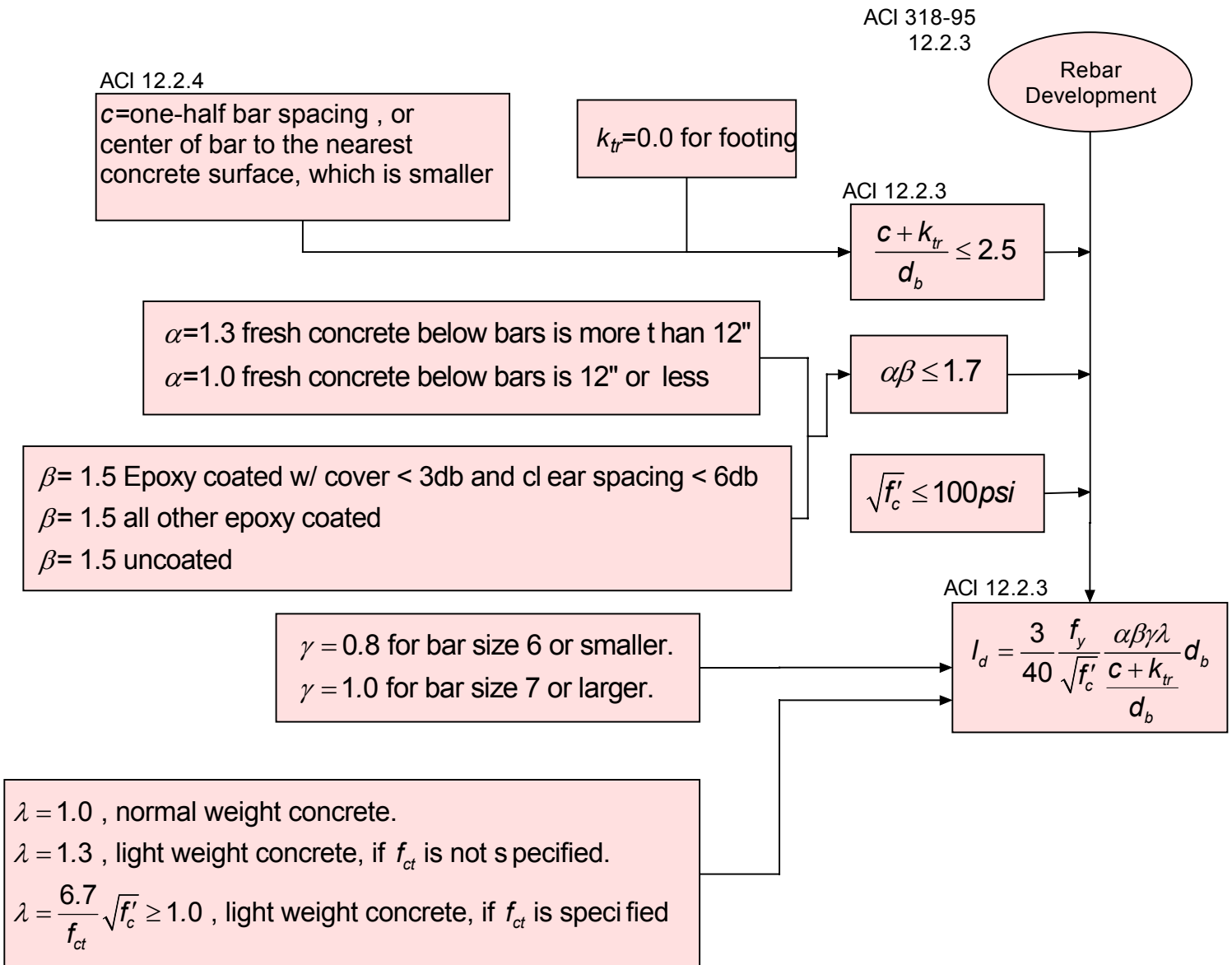
use deeper
section or higher
strength

use $\rho = \rho_{Min}$

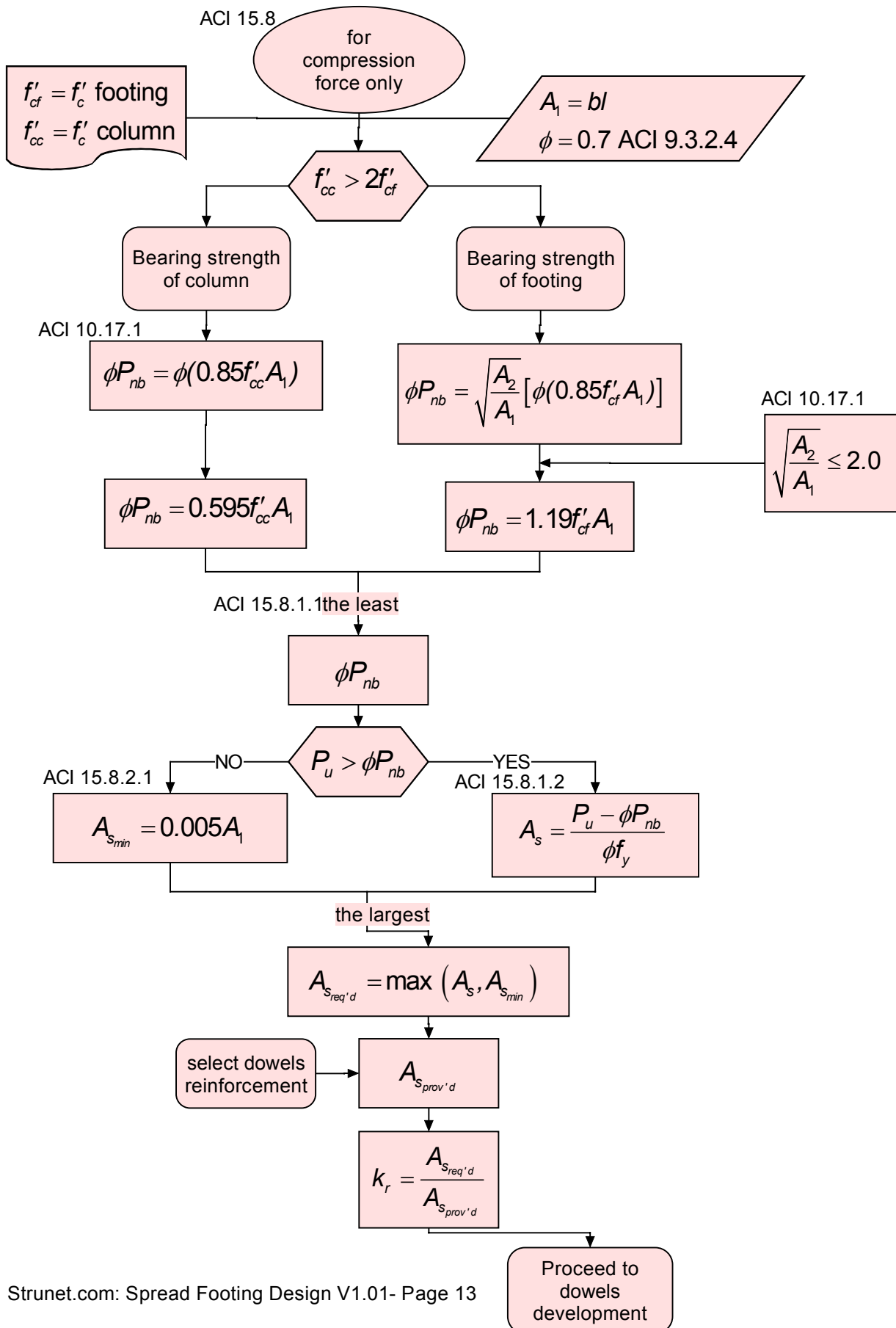
$$A_s = \rho b d \geq A_{smin} = \rho_{min} b h$$

proceed to rebar
development

Rebar Development



Forces Transfer at Column/Footing Interface



Column Dowels Development

