Rigid Pavement Mechanics

Dowel Bars

Allowable Bearing Stress

ACI Empirical Equation

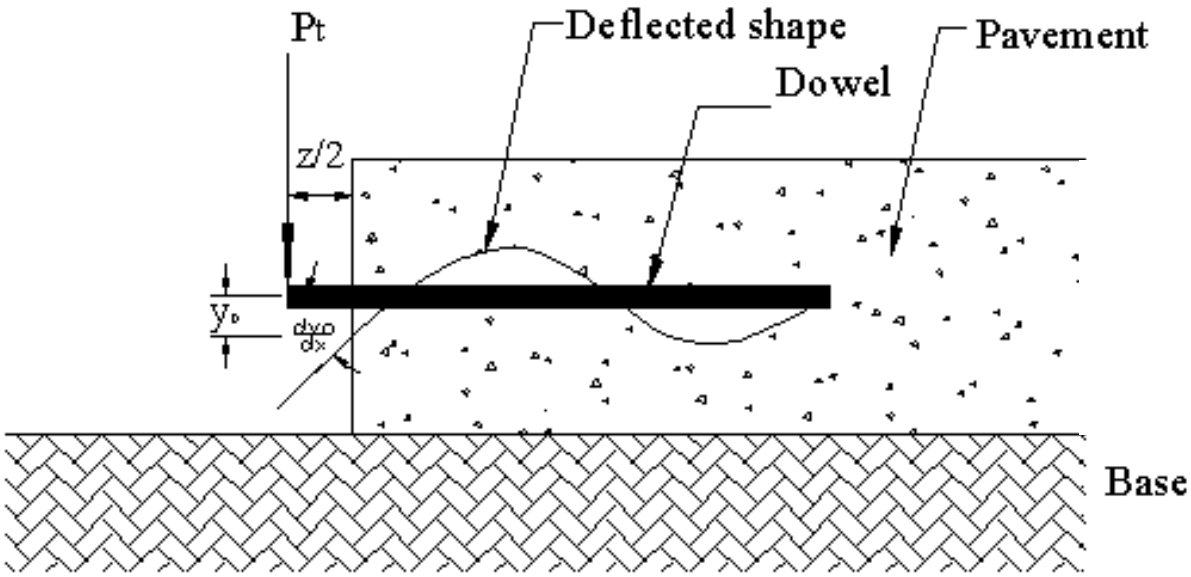
$$f_b = \left(\frac{4 - d}{3} \right) f_c'$$

f_b = allowable bearing stress

f_c' = concrete compressive strength

d = dowel bar diameter (in)

Bar Deformation Under Load



Bar Deformation Under Load

Freberg (1940)

$$y_o = \frac{P_c\left(2+\beta z\right)}{4\beta^3 E_d I_d}$$

P_c = load on the critical dowel bar

β = relative dowel/concrete stiffness

z = maximum joint opening (0.25 in)

Actual Bearing Stress

Freberg (1940)

$$\beta = \sqrt[4]{\frac{Kd}{4E_d I_d}} \qquad I_d = \frac{\pi d^4}{64}$$

E_d = elastic modulus of the dowel

I_d = moment of inertia of the dowel

d = bar diameter

Bearing Stress Under Load

Freberg (1940)

$$\sigma_b = Ky_o = \frac{KP_c\left(2+\beta z\right)_t}{4\beta^3 E_d I_d}$$

K = modulus of dowel support

$\left(300-1500 \text{ ksi/in}\right)$

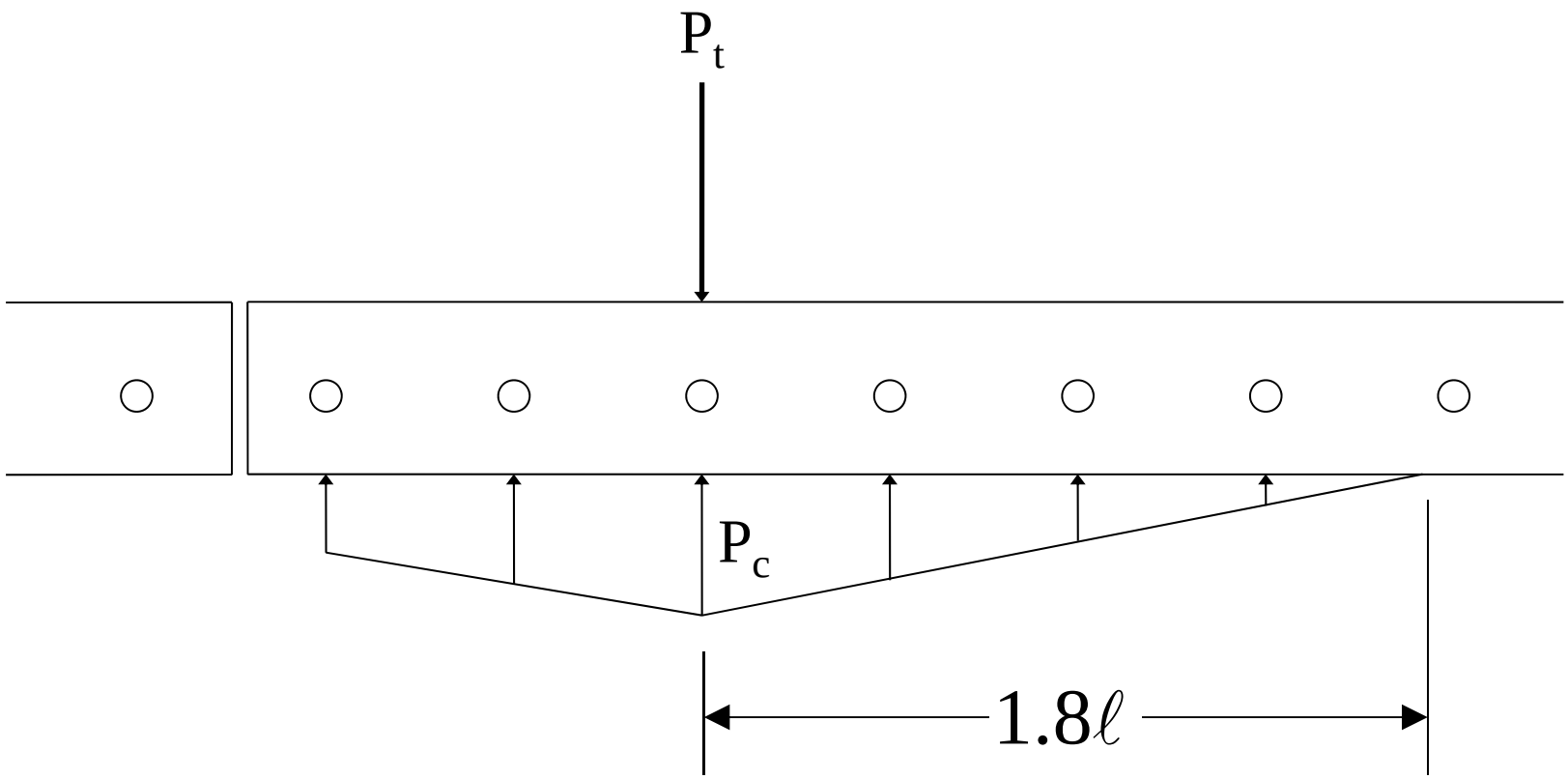
Modulus of Dowel Support

Freberg (1940)

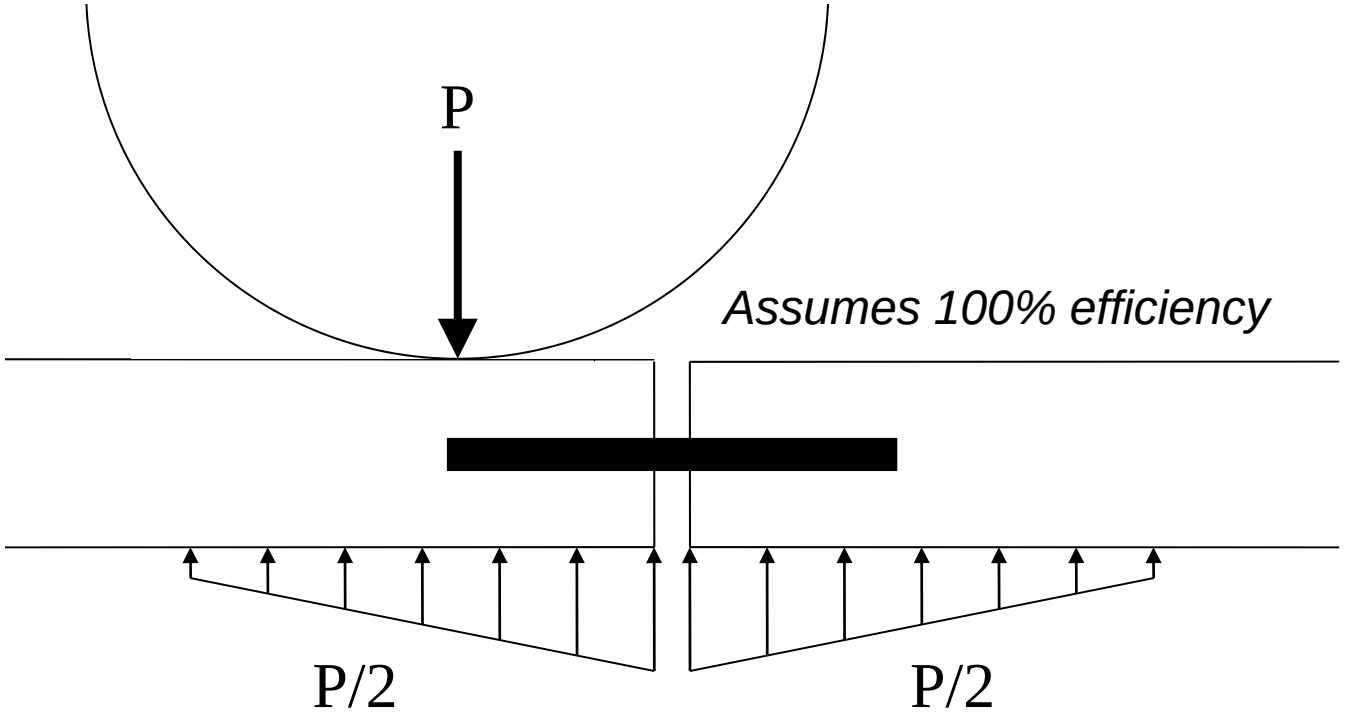
$$\sigma_b \propto \frac{K}{4\beta^3 E_d I_d} = \frac{\frac{K}{4EI}}{\left(\sqrt[4]{\frac{Kd}{4EI}}\right)^3} = \frac{\left(d^{1/3}\right)}{\sqrt[4]{\frac{\left(\frac{K}{4EI}\right)^4}{\left(\frac{K}{4EI}\right)^3}}} = \sqrt[4]{\frac{K}{4EI}}$$

$$\sigma_b \propto \sqrt[4]{K}$$

Dowel Spacing



Load Transfer



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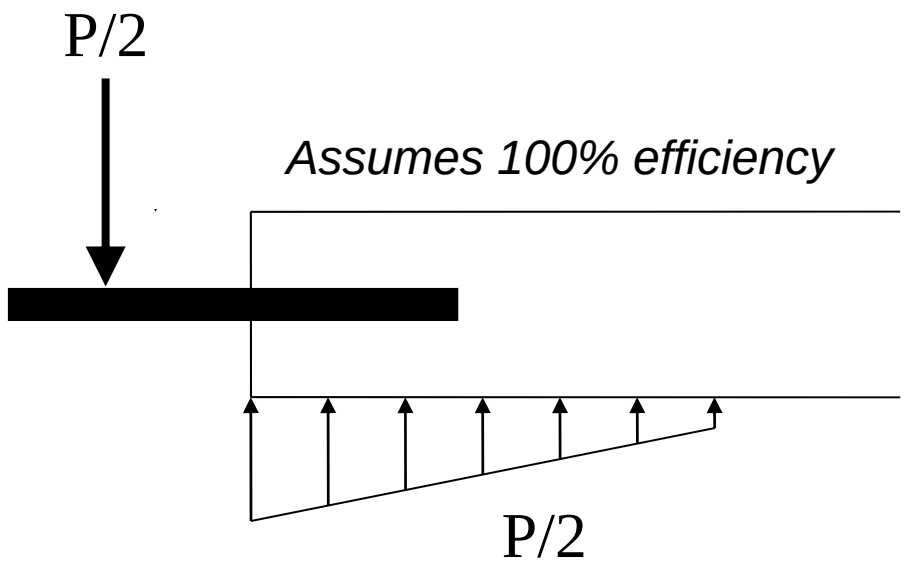

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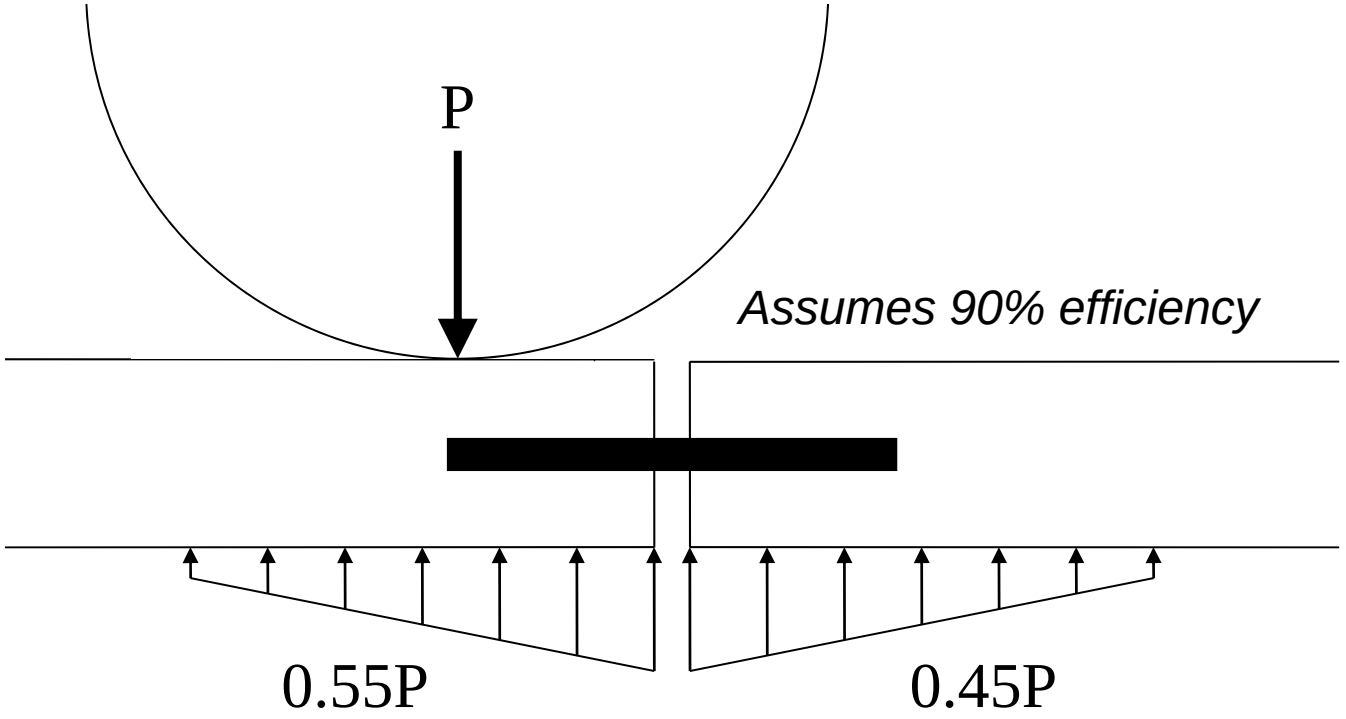

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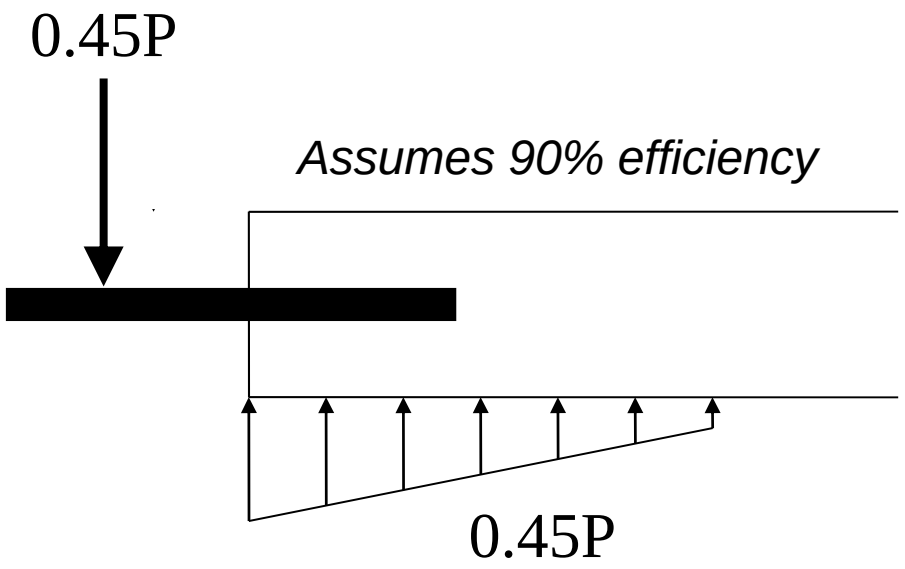


Example

Find the required dowel bar size for contraction joints in a 10" concrete slab resting on a subgrade material with a 200 psi/in modulus of subgrade reaction. The design load is a 9,000-lb dual wheel load centered 6" from the slab edge. Assume a 12" dowel spacing.

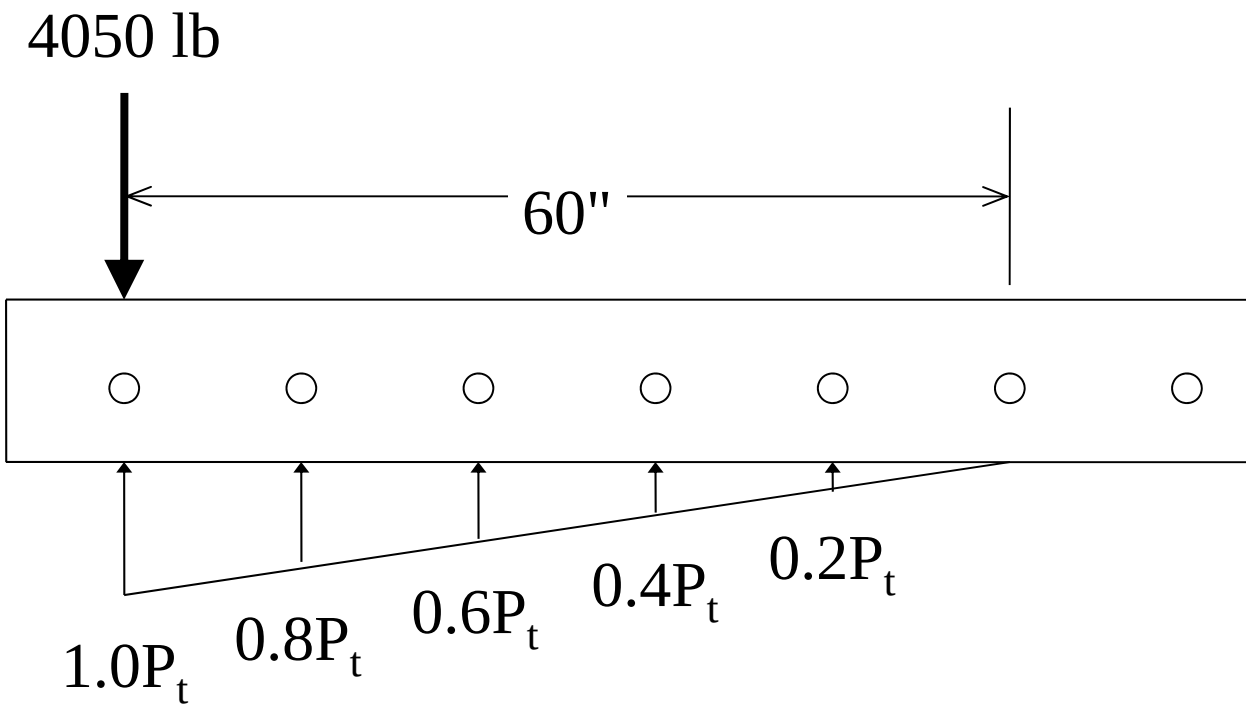
Example

$$\ell = \sqrt[4]{\frac{E_C h^3}{12\left(1-\nu^2\right)k}} = \sqrt[4]{\frac{\left(3{,}000{,}000\ psi\right)\left(1000\ in^3\right)}{12\left(0.9775\right)\left(200\ psi/in\right)}} = 33.6\ in$$

$$\Downarrow$$

$$1.8\ell \approx 60\ in$$

Example



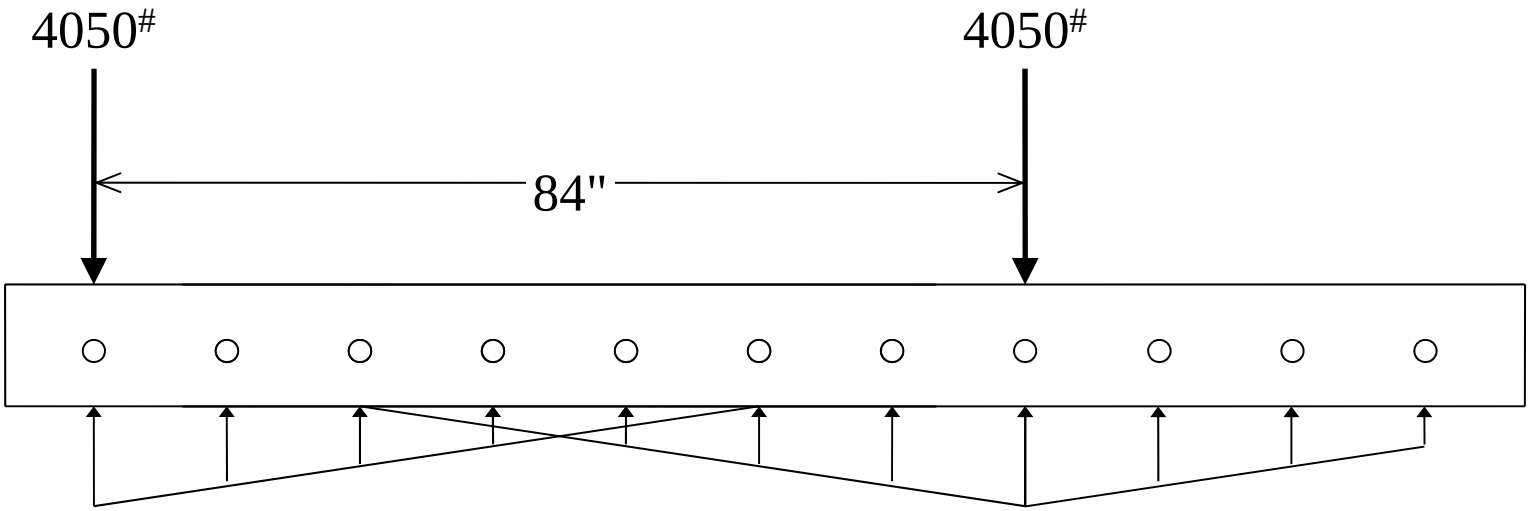
$$3.0P_t = 4050 \text{ lb}$$

Example

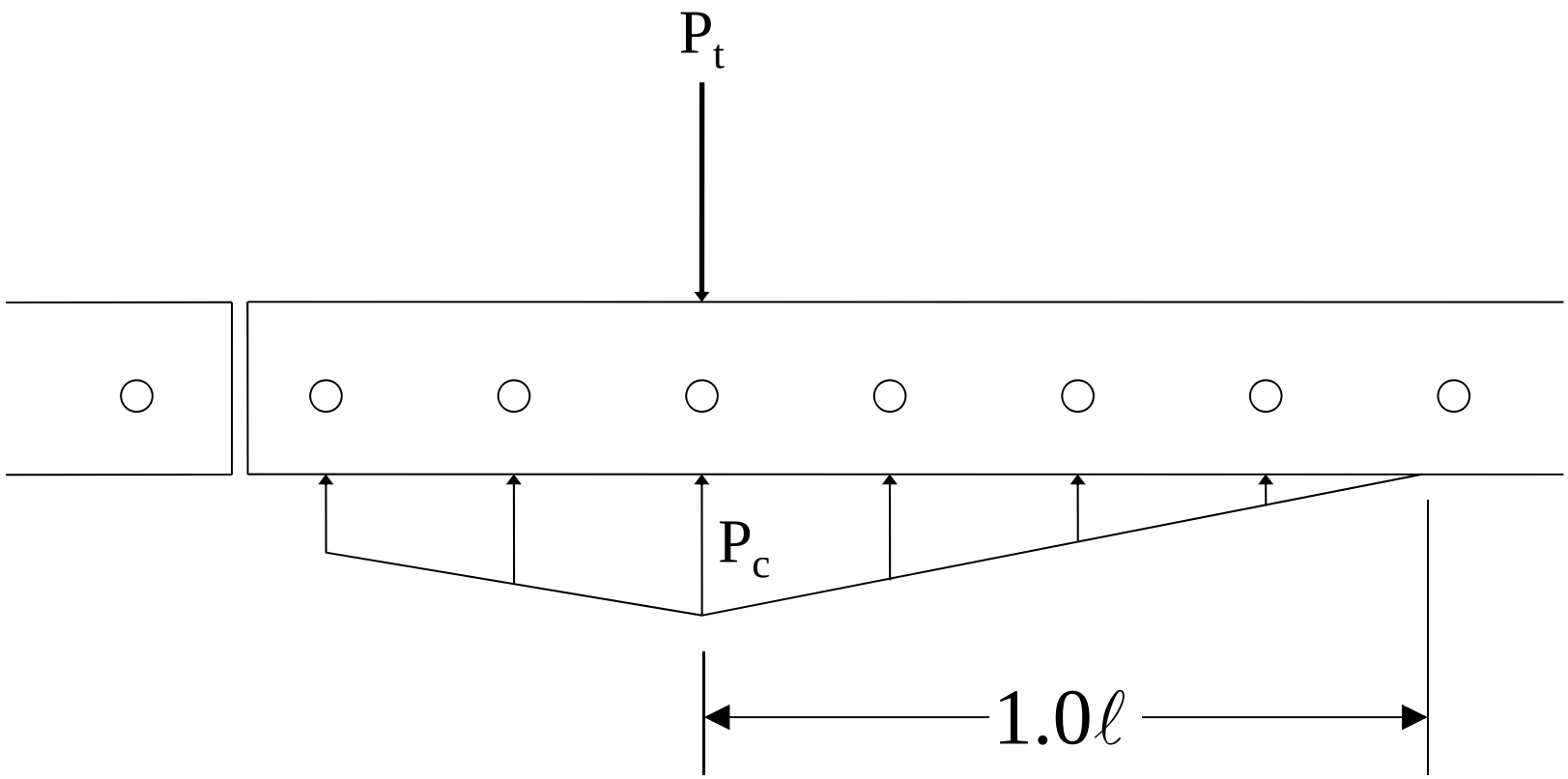
Assumptions

d = 1 in (Trial 1)
K = 1500 ksi/in
E = 30,000 ksi
z = 0.25 in

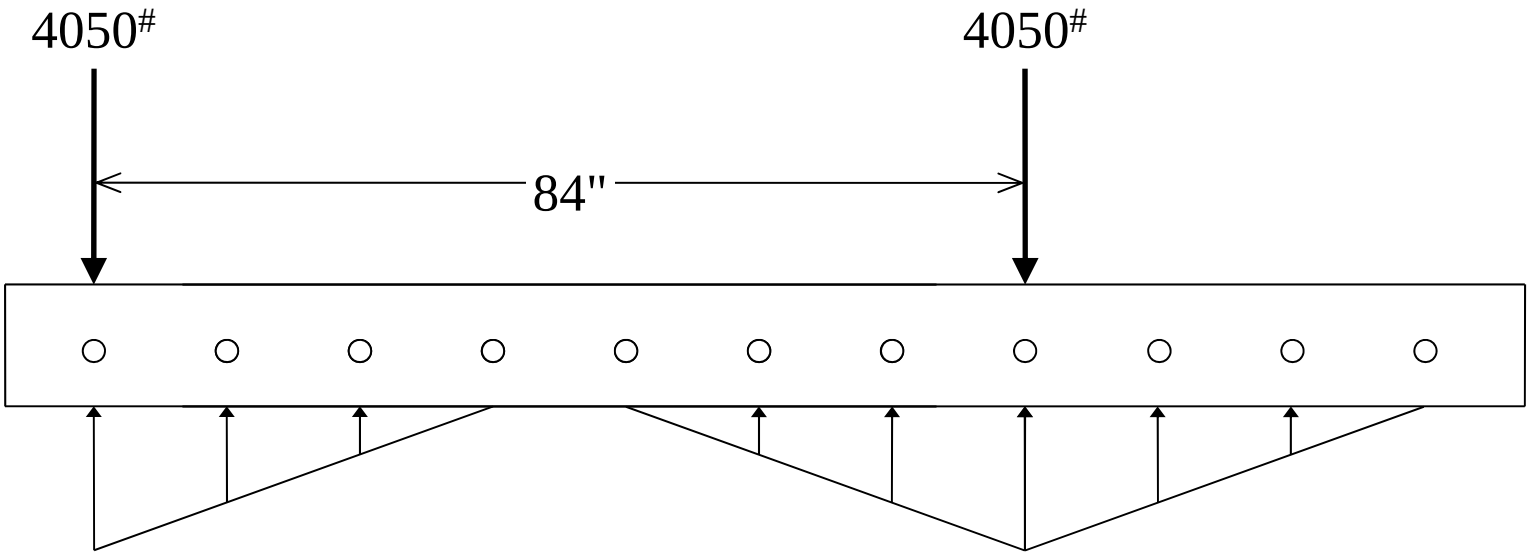
Multiple Wheel Loads



Dowel Spacing (Updated)



Dowel Spacing (Updated)



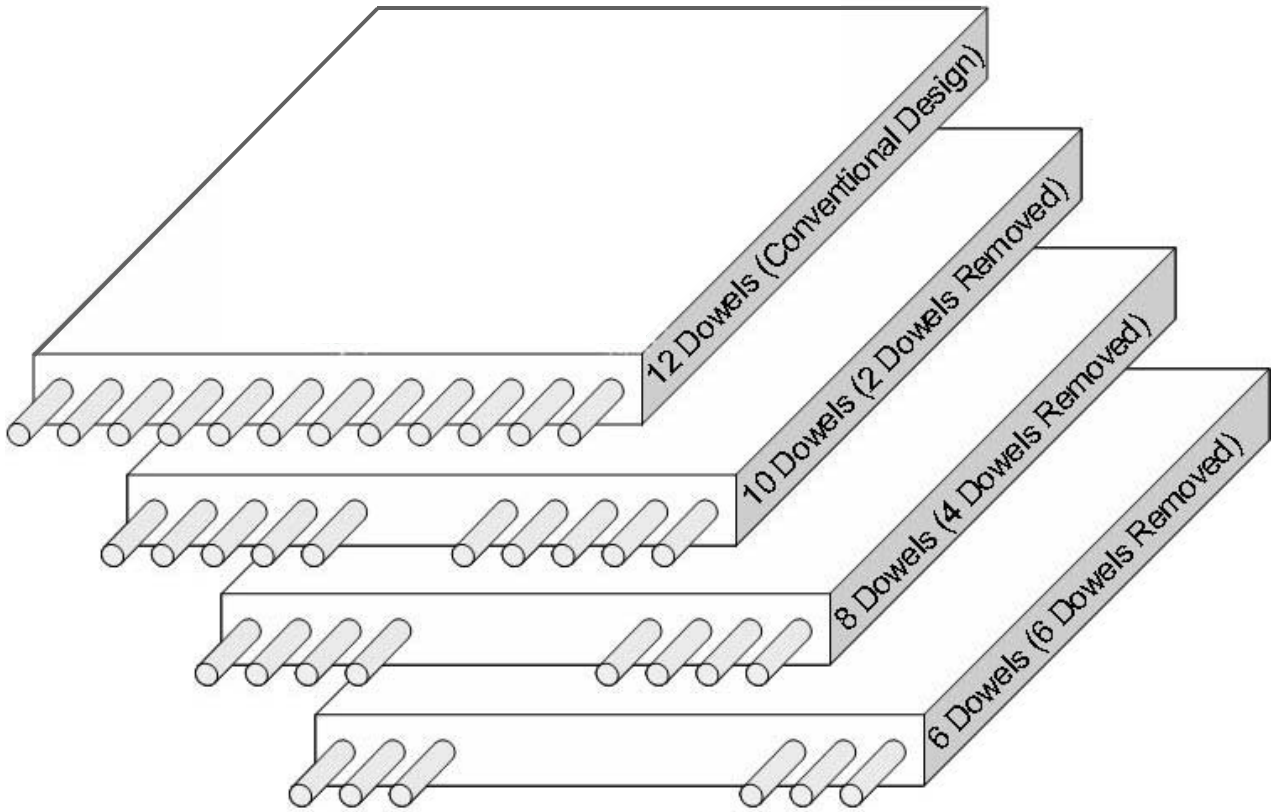
PCA Heuristics

Often, dowel bars are sized and spaced using heuristics.

AASHO originally recommended dowel diameters 1/8th the slab thickness, which is 1" for an 8" slab, 1.25" for a 10" slab, and 1.5" for a 12" slab.

PCA recommends using 1.25″ dowel bars for slabs up to 10″ thick and 1.5″ bars for slabs over 10″ thick. A common size is 1.5″ by 18″ or 20″ long. The most common spacing is 12″ center-to-center, but alternatives exist.

Alternative Dowel Spacing



Alternative Dowel Spacing