Prestress Losses

References	PCI Design Handbook, 8th Edition
Design File	Heavy IT Beam
Description	Calculation of prestress losses using the lump sum method present in the PCI Design Handbook.

Geometry

Height of precast section	$h_{pre} := 32\ in$
Width of stem	$w_{stem} := 24\ in$
Thickness of ledge	$t_{ledge} := 12\ in$
Width of ledge	$w_{ledge} := 8\ in$
Gross Cross Section Area	$A_g := 960\ in^2$
Composite Cross Section Area	$A_c := 1124\ in^2$
Area of Topping	$A_t := 2.75\ in \cdot 68\ in = 187\ in^2$
Centroid Location of the Gross Cross Section	$cg_y := 14\ in$
Centroid Location of the Composition Section	$cg_{yc} := 16.659\ in$
Height of the member	$h := 32\ in$
Gross Section Moment of Inertia	$I_{zz.g} := 83200\ in^4$
Composite Section Moment of Inertia	$I_{zz.c} := 132753.7\ in^4$

Material Properties

Initial Elast Modulus	$E_{ci} := 3586\ ksi$
30-Day Elastic Modulus	$E_{cf} := 4695\ ksi$
Relative Humidity	$R_h := 70$

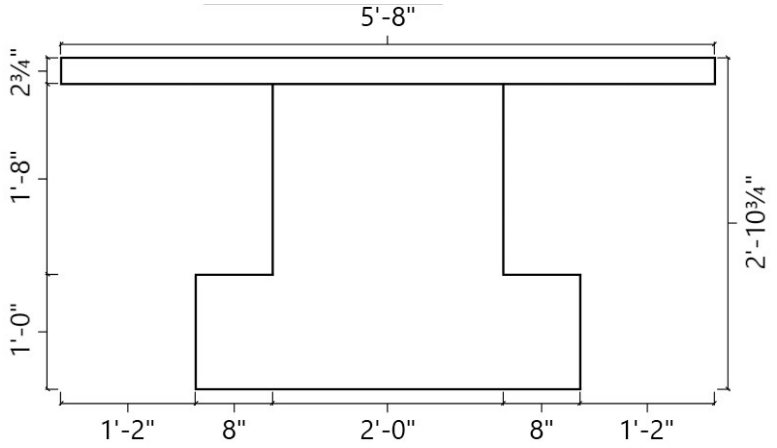

Figure 1: Concrete Geometry of Composite Precast IT Beam

Prestress Properties

Number of strand in rows 1-4	$num_{row1} := 16$
	$num_{row2} := 14$
	$num_{row3} := 2$

$num_{row4} := 2$

Centroid of strand in rows 1-4 measured from the bottom

$cg_{row1} := 3\ in$

$cg_{row2} := 5\ in$

$cg_{row3} := 10\ in$

$cg_{row4} := 30\ in$

Area of individual strand $A_{strand} := 0.167\ in^2$

Strand elastic modulus $E_{ps} := 29000\ ksi$

Strand ultimate Stress $f_{pu} := 270\ ksi$

Initial strand stress $f_{pi} := 0.75 \cdot f_{pu} = 202.5\ ksi$

Total area of strand $A_{ps} := A_{strand} \cdot \left(num_{row1} + num_{row2} + num_{row3} + num_{row4} \right) = 5.678\ in^2$

Centroid of strand

$$cg_{st} := \frac{num_{row1} \cdot cg_{row1} + num_{row2} \cdot cg_{row2} + num_{row3} \cdot cg_{row3} + num_{row4} \cdot cg_{row4}}{num_{row1} + num_{row2} + num_{row3} + num_{row4}} = 5.824\ in$$

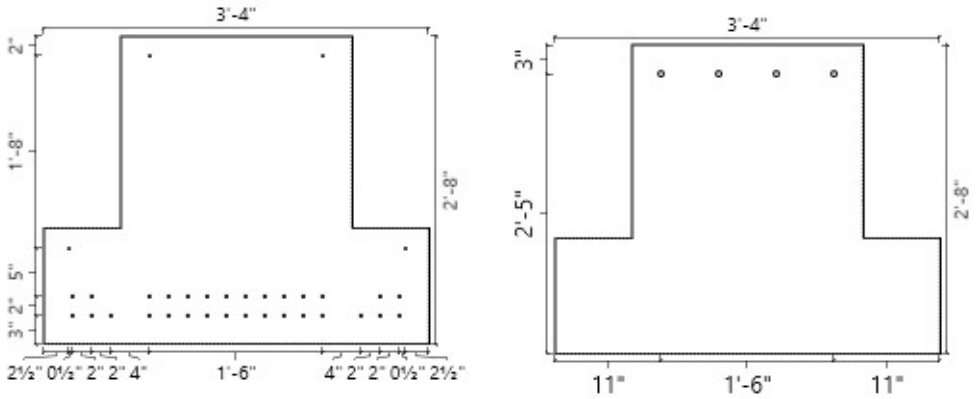

Figure 2: Reinforcement Locations of Strand (Left) and Rebar (Right)

Loading

Moment due to self weight $M_{SW} := 249.389\ kip\ ft$

Moment due to non-composite dead load $M_{Dnc} := 498.778\ kip\ ft$

Moment due to topping weight $M_{Dt} := 48.5789\ kip\ ft$

Moment due to composite dead load $M_{Dc} := 997.556\ kip\ ft$

Moment due to live load $M_{LL} := 748.167\ kip\ ft$

Elastic Shortening

Always 1.0 for prtestressed components $K_{es} := 1.0$

Strand eccentricity $e := cg_y - cg_{st} = 8.1765\ in$

Always 0.9 for prestressed components $K_{cir} := 0.9$

New compressive stress at centroid of strand (Equation 5-100)

$$f_{cir} := K_{cir} \cdot \left(\frac{A_{ps} \cdot f_{pi}}{A_g} + \frac{A_{ps} \cdot f_{pi} \cdot e^2}{I_{zz.g}} \right) - \frac{M_{SW} \cdot e}{I_{zz.g}} = 1615.3461\ psi$$

Elastic shortening (Equation 5-99) $ES := K_{es} \cdot \frac{E_{ps}}{E_{ci}} \cdot f_{cir} = 13063.3123\ psi$

Creep

2.0 for normalweight concrete $K_{cr} := 2.0$

Stress in concrete at centroid of strand due to super imposed permanent loads

Non composite loads $f_{cds.nc} := \frac{\left(M_{Dnc} + M_{Dt}\right) \cdot e}{I_{zz.g}} = 645.4972\ psi$

Composite loads $f_{cds.c} := \frac{M_{Dc} \cdot \left(cg_{yc} - cg_{st}\right)}{I_{zz.c}} = 977.0565\ psi$

Total Stress $f_{cds} := f_{cds.nc} + f_{cds.c} = 1622.5537\ psi$

Creep (Equation 5-101) $CR := K_{cr} \cdot \frac{E_{ps}}{E_{cf}} \cdot \left(f_{cir} - f_{cds}\right) = -89.0397\ psi$

Creep is strictly positive and will use 0 a lower bound.

$CR := 0\ psi$

Shrinkage

Perimeter of the precast section $Perimeter := 2 \cdot w_{stem} + 2 \cdot h + 4 \cdot w_{ledge} = 144\ in$

Volume to surface ratio $VS_{ratio} := \frac{A_g}{Perimeter} = 6.6667\ in$

1.0 for prestressed components $K_{sh} := 1.0$

Shrinkage (Equation 5-103) $SH := \left(8.2 \cdot 10^{-6}\right) \cdot K_{sh} \cdot E_{ps} \cdot \left(1 - \frac{0.06 \cdot VS_{ratio}}{in}\right) \cdot \left(100 - R_h\right) = 4280.4\ psi$

Relaxation

From table 5.8.1 $K_{re} := 5000\ psi$

From table 5.8.1 $J := 0.040$

Coefficient (Equation 5-105) $C := \frac{\frac{f_{pi}}{f_{pu}}}{0.21} \cdot \left(\frac{\frac{f_{pi}}{f_{pu}}}{0.9} - 0.55\right) = 1.0119$

Relaxation (Equation 5-104) $RE := C \cdot \left(K_{re} - J \cdot \left(SH + CR + ES\right)\right) = 4357.5164\ psi$

Live Load Regain

Stress at the centroid of strand due to live load

$f_{cll} := -\frac{M_{LL} \cdot \left(cg_{yc} - cg_{st}\right)}{I_{zz.c}} = -732.7924\ psi$

Total live load regain $LR := \frac{E_{ps}}{E_{cf}} \cdot f_{cll} = -4526.3\ psi$

Total Losses

Total losses $TL := ES + CR + SH + RE + LR = 17174.9286\ psi$

Percent prestress loss $Loss := \frac{TL}{f_{pi}} = 8.4814\ \%$