Square Footing Design

General Form of Equations referencing equations from ACI 318-19 as well as design methods from Principles of Foundation Engineering 3rd edition.

One-way Shear

$$P_{ult} = 1.2 * P_{DL} + 1.6 * P_{LL}$$

$$W_u = \frac{P_{ult}}{B}$$

$$V_u = W_u * \left(\frac{B-b}{2} - d\right)$$

$$V_n = 2 * B * b * \sqrt{f_c^{'}} * \frac{1\ kip}{1000\ lb}$$

$$\phi V_n > V_u$$

Two-way Shear

$$q_u = \frac{P_{ult}}{B^2}$$

$$V_u = q_u * \left[B^2 - (b + d)^2\right]$$

$$V_n = 4 * [4 * (b + d) * d] * \sqrt{f_c^{'}}$$

$$\phi V_n > V_u$$

Flexure

$$W_u = \frac{P_{ult}}{B}$$

$$M_u = \frac{1}{2} * W_u * \left(\frac{B-b}{2}\right)^2$$

$$a = \frac{A_s * f_y}{\beta_1 * f_c^{'} * B}$$

$$M_n = A_s * f_y * \left(d - \frac{a}{2}\right)$$

$$\phi M_n > M_u$$

Min Steel Requirement

$A_{s,min} = \rho_{min} * B * T$

$A_s > A_{s,min}$

Ductility

$\varepsilon_t = .003 * \left(\frac{d-c_n}{c_n}\right) > .005$ ✓

Footing 1

One-way Shear

$P_{DL} = 24.375\ kips$

$P_{LL} = 8.125\ kips$

$P_{ult} = 1.2 * 24.375\ kips + 1.6 * 8.125\ kips = 42.25\ kips$

$W_u = \frac{42.25\ kips}{3.5\ ft} = 12.1\ \frac{kips}{ft}$

$V_u = 12.1\ \frac{kips}{ft} * \left(\frac{3.5\ ft - 1\ ft}{2} - \left(9.5\ in * \frac{1\ ft}{12\ in}\right)\right) = 5.53\ kips$

$V_n = 2 * 3.5\ ft * 1\ ft * \sqrt{4000\ psi} * \frac{1\ kip}{1000\ lb} = 50.5\ kips$

$\phi V_n = 37.9\ kips > V_u = 5.53\ kips$ ✓

Two-way Shear

$q_u = \frac{42.25\ kips}{(3.5\ ft)^2} = 3.45\ \frac{kips}{ft^2}$

$V_u = 3.45\ \frac{kips}{ft^2} * \left[(3.5\ ft)^2 - \left(1\ ft + \left(9.5\ in * \frac{1\ ft}{12\ in}\right)\right)^2\right] = 31.2\ kips$

$V_n = 4 * \left[4 * \left(1\ ft + \left(9.5\ in * \frac{1\ ft}{12\ in}\right)\right) * \left(9.5\ in * \frac{1\ ft}{12\ in}\right)\right] * \sqrt{4000\ psi} = 206.7\ kips$

$\phi V_n = 155.01\ kips > V_u = 31.2\ kips$ ✓

Flexure

$W_u = \frac{42.25\ kips}{3.5\ ft} = 12.1\ \frac{kips}{ft}$

$M_u = \frac{1}{2} * 12.1\ \frac{kips}{ft} * \left(\frac{3.5\ ft - 1\ ft}{2}\right)^2 = 9.43\ kip - ft$

$a = \frac{1.84\ in^2 * 60\ ksi}{.85 * 4000\ psi * 3.5\ ft} = .77\ in$

$M_n = 1.84\ in^2 * 60\ ksi * \left(9.5\ in - \frac{.77\ in}{2}\right) = 83.8\ kip\ ft$

$\phi M_n = 83.8\ kip - ft > M_u = 9.43\ kip - ft$ ✓

Min Steel Requirement

$A_{s,min} = .0033 * 3.5\ ft * \frac{12\ in}{1\ ft} * 12\ in = 1.66\ in^2$

$A_s = 1.84\ in^2 > A_{s,min}$ ✓

Ductility

$\varepsilon_t = .003 * \left(\frac{9.5\ in - .91\ in}{.91}\right) = .028 > .005$ ✓

Footing 2

One-way Shear

$P_{DL} = 114\ kips$

$P_{LL} = 38\ kips$

$P_{ult} = 1.2 * 114\ kips + 1.6 * 38\ kips = 197.6\ kips$

$W_u = \frac{197.6\ kips}{6\ ft} = 32.9\ \frac{kips}{ft}$

$V_u = 32.9\ \frac{kips}{ft} * \left(\frac{6\ ft - 1\ ft}{2} - \left(15.5\ in * \frac{1\ ft}{12\ in}\right)\right) = 39.8\ kips$

$V_n = 2 * 6\ ft * 1\ ft * \sqrt{4000\ psi} * \frac{1\ kip}{1000\ lb} = 141.2\ kips$

$\phi V_n = 105.9\ kips\ > V_u = 39.8\ kips$ ✓

Two-way Shear

$q_u = \frac{197.6\ kips}{(6\ ft)^2} = 5.49\ \frac{kips}{ft^2}$

$V_u = 5.49\ \frac{kips}{ft^2} * \left[(6\ ft)^2 - \left(1\ ft + \left(15.5\ in * \frac{1\ ft}{12\ in}\right)\right)^2\right] = 168.8\ kips$

$V_n = 4 * \left[4 * \left(1\ ft + \left(15.5\ in * \frac{1\ ft}{12\ in}\right)\right) * \left(15.5\ in * \frac{1\ ft}{12\ in}\right)\right] * \sqrt{4000\ psi} = 431.3\ kips$

$\phi V_n = 323.5\ kips > V_u = 168.8\ kips$ ✓

Flexure

$W_u = \frac{197.6\ kips}{6\ ft} = 32.9\ \frac{kips}{ft}$

$M_u = \frac{1}{2} * 32.9\ \frac{kips}{ft} * \left(\frac{6\ ft - 1\ ft}{2}\right)^2 = 102.9\ kip - ft$

$a = \frac{2.65\ in^2 * 60\ ksi}{.85 * 4000\ psi * 6\ ft} = .65\ in$

$M_n = 2.65\ in^2 * 60\ ksi * \left(15.5\ in - \frac{.65\ in}{2}\right) = 201.1\ kip - ft$

$\phi M_n = 181\ kip - ft > M_u = 102.9\ kip - ft$ ✓

Min Steel Requirement

$A_{s,min} = .0033 * 6\ ft * \frac{12\ in}{1\ ft} * 18\ in = 2.33\ in^2$

$A_s = 2.65\ in^2 > A_{s,min}$ ✓

Ductility

$\varepsilon_t = .003 * \left(\frac{15.5\ in - .76\ in}{.76\ in}\right) = .06 > .005$ ✓

Footing 3

One-way Shear

$P_{DL} = 127.5\ kips$

$P_{LL} = 42.5\ kips$

$P_{ult} = 1.2 * 127.5\ kips + 1.6 * 42.5\ kips = 221\ kips$

$W_u = \frac{221\ kips}{6.5\ ft} = 34\ \frac{kips}{ft}$

$V_u = 34\ \frac{kips}{ft} * \left(\frac{6.5\ ft - 1\ ft}{2} - \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right) = 58.1\ kips$

$V_n = 2 * 6.5\ ft * 1\ ft * \sqrt{4000\ psi} * \frac{1\ kip}{1000\ lb} = 123.3\ kips$

$\phi V_n = 92.5\ kips > V_u = 58.1\ kips$ ✓

Two-way Shear

$q_u = \frac{221\ kips}{(6.5\ ft)^2} = 5.23\ \frac{kips}{ft^2}$

$V_u = 5.23 \frac{kips}{ft^2} * \left[(6.5\ ft)^2 - \left(1\ ft + \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right)^2\right] = 199.2\ kips$

$V_n = 4 * \left[4 * \left(1\ ft + \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right) * \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right] * \sqrt{4000\ psi} = 309.9\ kips$

$\phi V_n = 232.4\ kips > V_u = 199.2\ kips$ ✓

Flexure

$W_u = \frac{221\ kips}{6.5\ ft} = 34\ \frac{kips}{ft}$

$M_u = \frac{1}{2} * 34\ \frac{kips}{ft} * \left(\frac{6.5\ ft - 1\ ft}{2}\right)^2 = 128.6\ kip - ft$

$a = \frac{2.41\ in^2 * 60\ ksi}{.85 * 4000\ psi * 6.5\ ft} = .55\ in$

$M_n = 2.41\ in^2 * 60\ ksi * \left(12.5\ in - \frac{.55\ in}{2}\right) = 147.3\ kip - ft$

$\phi M_n = 132.6\ kip - ft > M_u = 128.6\ kip - ft$ ✓

Min Steel Requirement

$A_{s,min} = .0033 * 6.5\ ft * \frac{12\ in}{1\ ft} * 15\ in = 2.11\ in^2$

$A_s = 2.41\ in^2 > A_{s,min}$ ✓

Ductility

$\varepsilon_t = .003 * \left(\frac{12.5\ in - .64\ in}{.64\ in}\right) = .05 > .005$ ✓

Footing 4

One-way Shear

$P_{DL} = 33.7\ kips$

$P_{LL} = 11.2\ kips$

$P_{ult} = 1.2 * 33.7\ kips + 1.6 * 11.2\ kips = 58.4\ kips$

$W_u = \frac{58.4\ kips}{4\ ft} = 14.6\ \frac{kips}{ft}$

$V_u = 14.6\ \frac{kips}{ft} * \left(\frac{4\ ft - 1\ ft}{2} - \left(9.5\ in * \frac{1\ ft}{12\ in}\right)\right) = 10.3\ kips$

$V_n = 2 * 4\ ft * 1\ ft * \sqrt{4000\ psi} * \frac{1\ kip}{1000\ lb} = 57.7\ kips$

$\phi V_n = 43.3\ kips > V_u = 10.3\ kips$ ✓

Two-way Shear

$q_u = \frac{58.4\ kips}{(4\ ft)^2} = 3.65\ \frac{kips}{ft^2}$

$V_u = 3.65 \frac{kips}{ft^2} * \left[(4\ ft)^2 - \left(1\ ft + \left(9.5\ in * \frac{1\ ft}{12\ in}\right)\right)^2\right] = 46.7\ kips$

$V_n = 4 * \left[4 * \left(1\ ft + \left(9.5\ in * \frac{1\ ft}{12\ in}\right)\right) * \left(9.5\ in * \frac{1\ ft}{12\ in}\right)\right] * \sqrt{4000\ psi} = 206.7\ kips$

$\phi V_n = 155\ kips > V_u = 46.7\ kips$ ✓

Flexure

$W_u = \frac{58.4\ kips}{4\ ft} = 14.6\ \frac{kips}{ft}$

$M_u = \frac{1}{2} * 14.6\ \frac{kips}{ft} * \left(\frac{4\ ft - 1\ ft}{2}\right)^2 = 16.4\ kip - ft$

$a = \frac{2.21\ in^2 * 60\ ksi}{.85 * 4000\ psi * 4\ ft} = .81\ in$

$M_n = 2.21\ in^2 * 60\ ksi * \left(9.5\ in - \frac{.81\ in}{2}\right) = 100.5\ kip - ft$

$\phi M_n = 90.4\ kip - ft\ > M_u = 16.4\ kip - ft$ ✓

Min Steel Requirement

$A_{s,min} =.0033 * 4\ ft * \frac{12\ in}{1\ ft} * 12\ in = 1.9\ in^2$

$A_s = 2.21\ in^2\ > A_{s,min}$ ✓

Ductility

$\varepsilon_t =.003 * \left(\frac{9.5\ in - .96\ in}{.96\ in}\right) =.03\ >.005$ ✓

Footing 5

One-way Shear

$P_{DL} = 45\ kips$

$P_{LL} = 15\ kips$

$P_{ult} = 1.2 * 45\ kips + 1.6 * 15\ kips = 78\ kips$

$W_u = \frac{78\ kips}{4\ ft} = 19.5\ \frac{kips}{ft}$

$V_u = 19.5\ \frac{kips}{ft} * \left(\frac{4\ ft - 1\ ft}{2} - \left(9.5\ in * \frac{1\ ft}{12\ in}\right)\right) = 13.8\ kips$

$V_n = 2 * 4\ ft * 1\ ft * \sqrt{4000\ psi} * \frac{1\ kip}{1000\ lb} = 57.7\ kips$

$\phi V_n = 43.3\ kips > V_u = 13.8\ kips$ ✓

Two-way Shear

$q_u = \frac{78\ kips}{(4\ ft)^2} = 4.88\ \frac{kips}{ft^2}$

$V_u = 4.88 \frac{kips}{ft^2} * \left[(4\ ft)^2 - \left(1\ ft + \left(9.5\ in * \frac{1\ ft}{12\ in}\right)\right)^2\right] = 62.4\ kips$

$V_n = 4 * \left[4 * \left(1\ ft + \left(9.5\ in * \frac{1\ ft}{12\ in}\right)\right) * \left(9.5\ in * \frac{1\ ft}{12\ in}\right)\right] * \sqrt{4000\ psi} = 206.7\ kips$

$\phi V_n = 155\ kips > V_u = 62.4\ kips$ ✓

Flexure

$W_u = \frac{78\ kips}{4\ ft} = 19.5\ \frac{kips}{ft}$

$M_u = \frac{1}{2} * 19.5\ \frac{kips}{ft} * \left(\frac{4\ ft - 1\ ft}{2}\right)^2 = 21.9\ kip - ft$

$a = \frac{2.21\ in^2 * 60\ ksi}{.85 * 4000\ psi * 4\ ft} = .81\ in$

$M_n = 2.21\ in^2 * 60\ ksi * \left(9.5\ in - \frac{.81\ in}{2}\right) = 100.5\ kip - ft$

$\phi M_n = 90.4\ kip - ft\ > M_u = 21.9\ kip - ft$ ✓

Min Steel Requirement

$A_{s,min} = .0033 * 4\ ft * \frac{12\ in}{1\ ft} * 12\ in = 1.90\ in^2$

$A_s = 2.21\ in^2\ > A_{s,min}$ ✓

Ductility

$\varepsilon_t = .003 * \left(\frac{9.5\ in - .95\ in}{.95\ in}\right) = .026\ > .005$ ✓

Footing 6

One-way Shear

$P_{DL} = 192\ kips$

$P_{LL} = 64\ kips$

$P_{ult} = 1.2 * 192\ kips + 1.6 * 64\ kips = 332.8\ kips$

$W_u = \frac{332.8\ kips}{7.5\ ft} = 44.4\ \frac{kips}{ft}$

$V_u = 44.4\ \frac{kips}{ft} * \left(\frac{7.5\ ft - 1\ ft}{2} - \left(15.5\ in * \frac{1\ ft}{12\ in}\right)\right) = 86.9\ kips$

$V_n = 2 * 7.5\ ft * 1\ ft * \sqrt{4000\ psi} * \frac{1\ kip}{1000\ lb} = 176.5\ kips$

$\phi V_n = 132.3\ kips\ > V_u = 86.9\ kips$ ✓

Two-way Shear

$q_u = \frac{332.8\ kips}{(7.5\ ft)^2} = 5.92\ \frac{kips}{ft^2}$

$V_u = 5.92 \frac{kips}{ft^2} * \left[(7.5\ ft)^2 - \left(1\ ft + \left(15.5\ in * \frac{1\ ft}{12\ in}\right)\right)^2\right] = 301.7\ kips$

$V_n = 4 * \left[4 * \left(1\ ft + \left(15.5\ in * \frac{1\ ft}{12\ in}\right)\right) * \left(15.5\ in * \frac{1\ ft}{12\ in}\right)\right] * \sqrt{4000\ psi} = 431.3\ kips$

$\phi V_n = 323.5\ kips > V_u = 301.7\ kips$ ✓

Flexure

$W_u = \frac{332.8\ kips}{7.5\ ft} = 44.4\ \frac{kips}{ft}$

$M_u = \frac{1}{2} * 44.4\ \frac{kips}{ft} * \left(\frac{7.5\ ft - 1\ ft}{2}\right)^2 = 234.3\ kip - ft$

$a = \frac{5.41\ in^2 * 60\ ksi}{.85 * 4000\ psi * 7.5\ ft} = 1.1\ in$

$M_n = 5.41\ in^2 * 60\ ksi * \left(15.5\ in - \frac{1.1\ in}{2}\right) = 404.9\ kip - ft$

$\phi M_n = 364.4\ kip - ft\ > M_u = 234.3\ kip - ft$ ✓

Min Steel Requirement

$A_{s,min} = .0033 * 7.5\ ft * \frac{12\ in}{1\ ft} * 18\ in = 5.34\ in^2$

$A_s = 5.41\ in^2\ > A_{s,min}$ ✓

Ductility

$\varepsilon_t = .003 * \left(\frac{15.5\ in - 1.25\ in}{1.25\ in}\right) = .034\ > .005$ ✓

Footing 7

One-way Shear

$P_{DL} = 139.7\ kips$

$P_{LL} = 46.6\ kips$

$P_{ult} = 1.2 * 139.7\ kips + 1.6 * 46.6\ kips = 242.2\ kips$

$W_u = \frac{242.2\ kips}{6.5\ ft} = 37.3\ \frac{kips}{ft}$

$V_u = 37.3\ \frac{kips}{ft} * \left(\frac{6.5\ ft-1\ ft}{2} - \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right) = 63.7\ kips$

$V_n = 2 * 6.5\ ft * 1\ ft * \sqrt{4000\ psi} * \frac{1\ kip}{1000\ lb} = 123.3\ kips$

$\phi V_n = 94.5\ kips > V_u = 63.7\ kips$ ✓

Punching

$q_u = \frac{242.2\ kips}{(6.5\ ft)^2} = 5.73\ \frac{kips}{ft^2}$

$V_u = 5.73\frac{kips}{ft^2} * \left[(6.5\ ft)^2 - \left(1\ ft + \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right)^2\right] = 218.3\ kips$

$V_n = 4 * \left[4 * \left(1\ ft + \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right) * \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right] * \sqrt{4000\ psi} = 309.9\ kips$

$\phi V_n = 232.4\ kips > V_u = 218.3\ kips$ ✓

Flexure

$W_u = \frac{242.2\ kips}{6.5\ ft} = 37.3\ \frac{kips}{ft}$

$M_u = \frac{1}{2} * 37.3\ \frac{kips}{ft} * \left(\frac{6.5\ ft-1\ ft}{2}\right)^2 = 141\ kip - ft$

$a = \frac{53.93\ in^2*60\ ksi}{.85*4000\ psi*6.5\ ft} = .89\ in$

$M_n = 3.93\ in^2 * 60\ ksi * \left(12.5\ in - \frac{.89\ in}{2}\right) = 236.9\ kip - ft$

$\phi M_n = 213.2\ kip - ft\ > M_u = 141\ kip - ft$ ✓

Min Steel Requirement

$A_{s,min} =.0033 * 6.5\ ft * \frac{12\ in}{1\ ft} * 15\ in = 3.86\ in^2$

$A_s = 3.93\ in^2\ > A_{s,min}$ ✓

Ductility

$\varepsilon_t =.003 * \left(\frac{12.5\ in - 1.05\ in}{1.05\ in}\right) =.032\ \ >.005$ ✓

Footing 8

One-way Shear

$P_{DL} = 113.25\ kips$

$P_{LL} = 37.75\ kips$

$P_{ult} = 1.2 * 113.25\ kips + 1.6 * 37.75\ kips = 196.3\ kips$

$W_u = \frac{196.3\ kips}{6.5\ ft} = 30.2\ \frac{kips}{ft}$

$V_u = 30.2\ \frac{kips}{ft} * \left(\frac{6.5\ ft - 1\ ft}{2} - \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right) = 51.6\ kips$

$V_n = 2 * 6.5\ ft * 1\ ft * \sqrt{4000\ psi} * \frac{1\ kip}{1000\ lb} = 123.3\ kips$

$\phi V_n = 123.3\ kips\ > V_u = 51.6\ kips$ ✓

Two-way Shear

$q_u = \frac{196.3\ kips}{(6.5\ ft)^2} = 4.65\ \frac{kips}{ft^2}$

$V_u = 4.65 \frac{kips}{ft^2} * \left[(6.5\ ft)^2 - \left(1\ ft + \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right)^2\right] = 176.9\ kips$

$V_n = 4 * \left[4 * \left(1\ ft + \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right) * \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right] * \sqrt{4000\ psi} = 309.9\ kips$

$\phi V_n = 232.4\ kips > V_u = 176.9\ kips$ ✓

Flexure

$W_u = \frac{196.3\ kips}{6.5\ ft} = 30.2\ \frac{kips}{ft}$

$M_u = \frac{1}{2} * 30.2 \frac{kips}{ft} * \left(\frac{6.5\ ft - 1\ ft}{2}\right)^2 = 114.2\ kip - ft$

$a = \frac{3.93\ in^2 * 60\ ksi}{.85 * 4000\ psi * 6.5\ ft} = .89\ in$

$M_n = 3.93\ in^2 * 60\ ksi * \left(12.5\ in - \frac{.89\ in}{2}\right) = 236.9\ kip - ft$

$\phi M_n = 213.2\ kip - ft\ > M_u = 114.9\ kip - ft$ ✓

Min Steel Requirement

$A_{s,min} = .0033 * 6.5\ ft * \frac{12\ in}{1\ ft} * 15\ in = 3.86\ in^2$

$A_s = 3.93\ in^2\ > A_{s,min}$ ✓

Ductility

$\varepsilon_t = .003 * \left(\frac{12.5\ in - 1.05\ in}{1.05\ in}\right) = .032\ > .005$ ✓

Footing 9

One Way Shear

$P_{DL} = 144.75\ kips$

$P_{LL} = 48.25\ kips$

$P_{ult} = 1.2 * 144.75\ kips + 1.6 * 48.25\ kips = 250.9\ kips$

$W_u = \frac{250.9\ kips}{6.5\ ft} = 38.6\ \frac{kips}{ft}$

$V_u = 38.6\ \frac{kips}{ft} * \left(\frac{6.5\ ft - 1\ ft}{2} - \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right) = 65.9\ kips$

$V_n = 2 * 6.5\ ft * 1\ ft * \sqrt{4000\ psi} * \frac{1\ kip}{1000\ lb} = 123.3\ kips$

$\phi V_n = 123.3\ kips\ > V_u = 65.9\ kips$ ✓

Punching

$q_u = \frac{250.9\ kips}{(6.5\ ft)^2} = 5.94\ \frac{kips}{ft^2}$

$V_u = 5.94 \frac{kips}{ft^2} * \left[(6.5\ ft)^2 - \left(1\ ft + \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right)^2\right] = 226.1\ kips$

$V_n = 4 * \left[4 * \left(1\ ft + \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right) * \left(12.5\ in * \frac{1\ ft}{12\ in}\right)\right] * \sqrt{4000\ psi} = 309.9\ kips$

$\phi V_n = 232.4\ kips > V_u = 226.1\ kips$ ✓

Flexure

$W_u = \frac{250.9\ kips}{6.5\ ft} = 38.6\ \frac{kips}{ft}$

$M_u = \frac{1}{2} * 38.6 \frac{kips}{ft} * \left(\frac{6.5\ ft - 1\ ft}{2}\right)^2 = 146\ kip - ft$

$a = \frac{3.93\ in^2 * 60\ ksi}{.85 * 4000\ psi * 6.5\ ft} = .89\ in$

$M_n = 3.93\ in^2 * 60\ ksi * \left(12.5\ in - \frac{.89\ in}{2}\right) = 236.9\ kip - ft$

$\phi M_n = 213.2\ kip - ft\ > M_u = 146\ kip - ft$ ✓

Min Steel Requirement

$A_{s,min} =.0033 * 6.5\ ft * \frac{12\ in}{1\ ft} * 15\ in = 3.86\ in^2$

$A_s = 3.93\ in^2\ > A_{s,min}$ ✓

Ductility

$\varepsilon_t =.003 * \left(\frac{12.5\ in - 1.05\ in}{1.05\ in}\right) =.032\ >.005$ ✓

Final Square Footing Dimensions and Reinforcement

Table 122: Square Footing Dimensions and Reinforcement

Footing No.	Width [ft]	Length [ft]	Thickness [inch]	Bar No. [-]	Quantity of bars [-]
1	3.5	3.5	12	5	6
2	6.0	6.0	18	6	6
3	6.5	6.5	15	7	4
4	4.0	4.0	12	6	5
5	4.0	4.0	12	6	5
6	7.5	7.5	18	7	9
7	6.5	6.5	15	8	5
8	6.5	6.5	15	8	5
9	6.5	6.5	15	8	5

Continuous Footing Design utilizing ASDIP:

For the continuous footing we utilized ASDIP to calculate the required sizing and steel. The values obtained from ASDIP are a result of the wall loads that are being transferred to the foundation. These loads were calculated by calculating the weight of the wall per linear foot. The loads include the weight of a 9 inch concrete wall, brick exterior finish and insulation. These loads represent a load of 7.7 k-ft. After performing the analysis utilizing the software we found that the required width to be 3 ft and a thickness of 1.5 ft.

Table 123: Strip Footing Dimensions and Steel Reinforcement

Strip Footing Dimensions	
Width [ft]	3.5
Length [ft]	3.5
Thickness [ft]	1.5

	Bar No.	Spacing [inch]
Wall Dowels	5	12

Reinforcement Location	Along Wall		Perpendicular to wall	
	Bar No.	Quantity	Bar No.	Spacing [inch]
Top Reinforcement	6	12	4	6
Bottom Reinforcement	5	12	4	6

Through iterative runs we found that the required geometry of the strip footing required was 3.5 ft in width and 1.5 ft in thickness. The allowable soil pressure we utilized was significantly higher than the max bearing pressure that was applied using the 7.7 k/ft load.

SOIL BEARING PRESSURES

Allow. Bearing Pressure	3.7	ksf	
Max. Bearing Pressure	1.8	ksf	✓
Area in Contact with Soil	100.0	%	
Eccentricity / Ftg. Width	0.00 < 0.50		✓

BEARING PRESSURES ARE OK

STABILITY CHECK

Overturning Safety Factor	99.99 > 1.50	✓
Sliding Safety Factor	99.99 > 1.50	✓
Uplift Safety Factor	99.99 > 1.00	✓

STABILITY CHECK IS OK

LOAD TRANSFER

Wall Bearing Strength Ratio	0.04	✓
Footing Bearing Strength Ratio	0.02	✓
Shear Friction Strength Ratio	0.00	✓
Min. Wall Steel Area Ratio	0.21	✓
Dev. Length Ratio at Wall	0.33	✓
Dev. Length Ratio at Footing	0.48	✓

LOAD TRANSFER IS OK

REINFORCEMENT DESIGN

- Top Bars	Mu	ϕMn	Ratio	
X-Bars (k-ft/ft) ..	0.0	27.8	0.00	✓
X-Bars Develop. Length Ratio			0.83	✓
Min. Top Steel Area Ratio			0.97	✓
- Bottom Bars	**Mu**	**ϕMn**	**Ratio**	
X-Bars (k-ft/ft) ..	2.1	26.9	0.08	✓
X-Bars Develop. Length Ratio			0.83	✓
Min. Bottom Steel Area Ratio			0.97	✓

REINFORCEMENT IS OK

SHEAR DESIGN

	Vu	ϕVn	Ratio	
One-way (k/ft) ...	9.8	43.3	0.22	✓

SHEAR DESIGN IS OK

Figure 73: Strip Footing At a Glance Parameters

Our one way shear applied to the footing was much lower than the nominal strength of the footing in shear. The stability check of the footing also was not an issue in the design we implemented.

GEOMETRY

Footing Width	3.50	ft	
Footing Thickness	18.0	in	OK
Soil Cover	0.00	ft	
Water Table	50.00	ft	
Wall Thickness	9.0	in	
Wall Offset	0.0	in	OK

SOIL BEARING (Comb: Service)

Gross Allow. Soil Pressure	3.7	ksf	
Max. Bearing Pressure	1.8	ksf	
Min. Bearing Pressure	1.8	ksf	
Bearing Pressure Ratio	0.49		OK
Ftg. Area in Contact w/ Soil	100.0	%	
Eccentricity / Ftg. Width	0.00		OK

APPLIED LOADS

	Service	Factored	
Axial Force P	5.5	7.7	k/ft
Moment about Z Mz	0.0	0.0	k-ft/ft
Shear Force Vx	0.0	0.0	k/ft

DESIGN CODES

Concrete Design	ACI 318-19
Load Combinations	Pre-combined

OVERTURNING CALCULATIONS (Comb: Service)

- Overturning about Z-Z

- Moment Mz = 0.0 k-ft/ft
- Shear Force Vx = 0.0 k/ft
  Arm = 0.00 + 18.0 / 12 = 1.50 ft   Moment = 0.0 * 1.5 = 0.0 k-ft/ft
- Passive Force = 0.0 k/ft   Arm = 0.60 ft   Moment = 0.0 * 0.60 = 0.0 k-ft/ft
- Overturning moment Z-Z = 0.0 + 0.0 = 0.0 k-ft/ft

- Resisting about Z-Z

- Footing weight = *W * L * Thick * Density* = 1.00 * 3.50 * 18.0 / 12 * 0.15 = 0.8 k/ft
  Arm = *L / 2* = 3.50 / 2 = 1.75 ft   Moment = 0.8 * 1.75 = 1.4 k-ft/ft
- Soil cover = *W * L * SC * Density* = (1.00 * 3.50 - 12.0 / 12 * 9.0 / 12) * 0.0 * 104 = 0.0 k/ft
  Arm = *L / 2* = 3.50 / 2 = 1.75 ft   Moment = 0.0 * 1.75 = 0.0 k-ft/ft
- Buoyancy = *W * L * γ * (SC + Thick - WT)* = 1.00 * 3.50 * 62 * (0.00 + 18.0 / 12 - 50.00) = 0.0 k/ft
  Arm = *L / 2* = 3.50 / 2 = 1.75 ft   Moment = 0.0 * 1.75 = 0.0 k-ft/ft
- Axial force P = 5.5 k/ft

Figure 74: ASDIP Calculations

Utilizing ASDIP we did not include the shear and moment loads on the wall. Future design should have the moment and shear implemented in design as a significant portion of the wall would be designed as shear walls. These shear walls would work to resist the lateral loads from an earthquake. We expect that the implementation of the shear walls load would increase the demand on our strip footing and we would have a significant overturning moment and shear load.

OVERTURNING CALCULATIONS (Comb: Service)

- Overturning about Z-Z

- Moment Mz = 0.0 k-ft/ft
- Shear Force Vx = 0.0 k/ft
  Arm = 0.00 + 18.0 / 12 = 1.50 ft   Moment = 0.0 * 1.5 = 0.0 k-ft/ft
- Passive Force = 0.0 k/ft   Arm = 0.60 ft   Moment = 0.0 * 0.60 = 0.0 k-ft/ft
- Overturning moment Z-Z = 0.0 + 0.0 = 0.0 k-ft/ft

- Resisting about Z-Z

- Footing weight = *W * L * Thick * Density =* 1.00 * 3.50 * 18.0 / 12 * 0.15 = 0.8 k/ft
  Arm = *L / 2 =* 3.50 / 2 = 1.75 ft   Moment = 0.8 * 1.75 = 1.4 k-ft/ft
- Soil cover = *W * L * SC * Density =* (1.00 * 3.50 - 12.0 / 12 * 9.0 / 12) * 0.0 * 104 = 0.0 k/ft
  Arm = *L / 2 =* 3.50 / 2 = 1.75 ft   Moment = 0.0 * 1.75 = 0.0 k-ft/ft
- Buoyancy = *W * L * γ * (SC + Thick - WT) =* 1.00 * 3.50 * 62 * (0.00 + 18.0 / 12 - 50.00) = 0.0 k/ft
  Arm = *L / 2 =* 3.50 / 2 = 1.75 ft   Moment = 0.0 * 1.75 = 0.0 k-ft/ft
- Axial force P = 5.5 k/ft
  Arm = *L / 2 - Offset =* 3.50 / 2 - 0.0 / 12 = 1.75 ft   Moment = 5.5 * 1.75 = 9.6 k-ft/ft
- Resisting moment Z-Z = 1.4 + 0.0 + 0.0 + 9.6 = 11.0 k-ft/ft
- Overturning safety factor Z-Z = $\dfrac{\textit{Resisting moment}}{\textit{Overturning moment}} = \dfrac{11.0}{0.0}$ = 99.99 > 1.50 OK

SOIL BEARING PRESSURES (Comb: Service)

Overturning moment Z-Z = 0.0 + 0.0 = 0.0 k-ft/ft

Resisting moment Z-Z = 1.4 + 0.0 + 0.0 + 9.6 = 11.0 k-ft/ft

Resisting force = *Footing + Soil - Buoyancy + P =* 0.8 + 0.0 - 0.0 + 5.5 = 6.3 k/ft

X-coordinate of resultant from maximum bearing corner:

$$Xp = \frac{\textit{Z-Resisting moment - Z-Overturning moment}}{\textit{Resisting force}} = \frac{11.0 - 0.0}{6.3} = 1.75 \text{ ft}$$

X-ecc = *Width / 2 - Xp =* 3.50 / 2 - 1.75 = 0.00 ft

Area = *Width * Length =* 1.00 * 3.50 = 3.5 ft²

Sz = *Length * Width² / 6 =* 1.00 * 3.50² / 6 = 2.0 ft³

Bearing length = *Min (Width , 3 * Xp)* = Min (3.50, 3 * 1.75) = 3.50 ft = Ftg. Width = 3.50 ft

Max. bearing = *Rv * (1/A + X-ecc / Sz) =* 6.3 * (1 / 3.5 + 0.00 / 2.0) = 1.8 ksf   < 3.7 ksf OK

Min. bearing = *Rv * (1/A - X-ecc / Sz) =* 6.3 * (1 / 3.5 - 0.00 / 2.0) = 1.8 ksf

Figure 75: ASDIP Overturning and Soil Bearing Pressure Calculations

SLIDING CALCULATIONS (Comb: Service)

Internal friction angle = 28 deg (assumed) Active coefficient ka = 0.00

Passive coefficient *kp = 1 / ka* = 1 / 0.00 = 4.33

Pressure at mid-depth = *kp * Density * (Cover + Thick / 2)* = 4.33 * 104 / 1000 * (0.00 + 18.0 / 12 / 2) = 0.34 ksf

X-Passive force = *Pressure * Thick * Length* = 0.34 * 18.0 / 12 * 1.00 = 0.5 k/ft

Friction force = *Resisting force * Friction coeff.* = Max (0, 6.3 * 0.45) = 2.8 k/ft

Use 100% of Passive + 100% of Friction for sliding resistance

- Sliding safety factor X-X = $\frac{\textit{X-Passive force + Friction}}{\textit{X-Horizontal load}} = \frac{1.00 * 0.5 + 1.00 * 2.8}{0.0}$ = 99.99 > 1.50 OK

UPLIFT CALCULATIONS (Comb: Service)

- Uplift safety factor = $\frac{\textit{Footing + Cover - Buoyancy}}{\textit{Uplift load}} = \frac{0.8 + 0.0 - 0.0}{0.0}$ = 99.99 > 1.00 OK

SHEAR CALCULATIONS (Comb: Factored)

Concrete f'c = 4.0 ksi Steel fy = 60.0 ksi Soil density = 104 pcf

d Top X-dir = *Thick - Cover - X-diameter / 2* = 18.0 - 2.0 - 0.5 / 2 = 15.8 in

d Top Z-dir = *Thick - Cover - X-diameter - Z-diameter / 2* = 18.0 - 2.0 - 0.5 - 0.8 / 2 = 15.1 in

d Bot X-dir = *Thick - Cover - X-diameter / 2* = 18.0 - 2.5 - 0.5 / 2 = 15.3 in

d Bot Z-dir = *Thick - Cover - X-diameter - Z-diameter / 2* = 18.0 - 2.5 - 0.5 - 0.6 / 2 = 14.7 in

*ϕVcx = 8 * ρ⅓ * √f'c * Width * d* = 8 * (0.0022)⅓ * √(4000) * 3.5 * 12 * 15.3 / 1000 = 9.2 kip ACI 22.5.5.1

- Shear forces calculated as the volume of the bearing pressures under the effective areas:

One-way shear Vux (- Side) = 0.3 k/ft < 9.2 k/ft OK

One-way shear Vux (+ Side) = 0.3 k/ft < 9.2 k/ft OK

Figure 76: ASDIP Sliding, Uplift, and Shear Calculations

The Shear Calculations utilized are only taking into account the one way shear that the wall would be placing into the strip footing. These loads of one way shear were calculated to 0.3 k/ft and are lower than the factored nominal shear capacity of 9.2 k/ft.

BENDING CALCULATIONS (Comb: Factored)

Plain ϕMnz = *5 * ϕ * √(f'c) * W * Thick^2 / 6* = 5 * 0.55 * √(4000) * 1.00 * 18.0^2 / 6 / 1000 = 9.4 k-ft/ft ACI Eq. (14.5.2.1a)

- Top Bars

Use 12 #6 Z-Bars *ρ = As / b d* = 5.3 / (3.50 * 12 * 15.1) = 0.0083 q = 0.0083 * 60 / 4.0 = 0.125

Use #4 @ 6.0 in X-Bars *ρ = As / b d* = 0.4 / (1.00 * 12 * 15.8) = 0.0021 q = 0.0021 * 60 / 4.0 = 0.032

Bending strength *ϕMn = ϕ * b * d^2 * fc * q * (1 - 0.59 * q)* ACI 22.2.2

ϕMnz = 0.90 * 1.00 * 12 * 15.8^2 * 4.0 * 0.032 * (1 - 0.59 * 0.032) = 27.8 k-ft/ft

- Top moments calculated as the overburden minus the bearing pressures times the lever arm:

Top moment -Muz (- Side) = 0.0 k-ft/ft < 27.8 k-ft/ft OK

Top moment -Muz (+ Side) = 0.0 k-ft/ft < 27.8 k-ft/ft OK

X-As min = *0.0018 * Length * Thick* =0.0018 * 1.00 * 12 * 18.0 = 0.4 in^2/ft < 0.4 in^2/ft OK

Z-As min = *0.0018 * Width * Thick* = 0.0018 * 3.50 * 12 * 18.0 = 1.4 in^2 < 5.3 in^2 OK ACI 8.6.1.1

X-Cover factor = *Min (2.5, (Cover + db /2, Spacing / 2) / db)* = Min (2.5, (2.0 + 0.50 / 2, 6.0 / 2) / 0.50) = 2.5

Straight *X-Ld = Max (12.0, 3 / 40 * fy / (fc)½ * Grade * Size * Location / Cover * db * ratio)* ACI Eq. (25.4.2.4a)

X-Ld = Max (12.0, 3 / 40 * 60.0 * 1000 / (4000)½ * 1.0 * 0.8 * 1.3 / 2.5 * 0.50 * 0.00) = 12.0 in

Hooked *X-Ldh = Max (8 db, 6, 1 / 55 * fy / (fc)½ * Confining * Location * Concrete * db^1.5)* = ACI 25.4.3

X-Ldh = Max (8 db, 6, 1 / 55 * 60.0 * 1000 / (4000)½ * 1.0 * 1.0 * 0.9 * 0.50^1.5) = 6.0 in

-X Ld provided = *(Width - Wall) / 2 + Offset - Cover* = 3.50 * 12 / 2 + 0.0 - 9.0 / 2 - 2.0 = 14.5 in > 12.0 in OK

+X Ld provided = *(Width - Wall) / 2 - Offset - Cover* = 3.50 * 12 / 2 - 0.0 - 9.0 / 2 - 2.0 = 14.5 in > 12.0 in OK

- Bottom Bars

Use 12 #5 Z-Bars *ρ = As / b d* = 3.7 / (3.50 * 12 * 14.7) = 0.0060 q = 0.0060 * 60 / 4.0 = 0.090

Use #4 @ 6.0 in X-Bars *ρ = As / b d* = 0.4 / (1.00 * 12 * 15.3) = 0.0022 q = 0.0022 * 60 / 4.0 = 0.033

Bending strength *ϕMn = ϕ * b * d^2 * fc * q * (1 - 0.59 * q)* ACI 22.2.2

ϕMnz = 0.90 * 1.00 * 12 * 15.3^2 * 4.0 * 0.033 * (1 - 0.59 * 0.033) = 26.9 k-ft/ft

- Bottom moments calculated as the bearing minus the overburden pressures times the lever arm:

Bottom moment Muz (- Side) = 2.1 k-ft/ft < 26.9 k-ft/ft OK ratio = 0.08

Bottom moment Muz (+ Side) = 2.1 k-ft/ft < 26.9 k-ft/ft OK ratio = 0.08

X-As min = *0.0018 * Length * Thick* =0.0018 * 1.00 * 12 * 18.0 = 0.4 in^2/ft < 0.4 in^2/ft OK

Z-As min = *0.0018 * Width * Thick* = 0.0018 * 3.50 * 12 * 18.0 = 1.4 in^2 < 3.7 in^2 OK

X-Cover factor = *Min (2.5, (Cover + db /2, Spacing / 2) / db)* = Min (2.5, (2.5 + 0.50 / 2, 6.0 / 2) / 0.50) = 2.5

Straight *X-Ld = Max (12.0, 3 / 40 * fy / (fc)½ * Grade * Size * Location / Cover * db * ratio)* ACI Eq. (25.4.2.4a)

X-Ld = Max (12.0, 3 / 40 * 60.0 * 1000 / (4000)½ * 1.0 * 0.8 * 1.0 / 2.5 * 0.50 * 0.08) = 12.0 in

Hooked *X-Ldh = Max (8 db, 6, 1 / 55 * fy / (fc)½ * Confining * Location * Concrete * db^1.5)* = ACI 25.4.3

X-Ldh = Max (8 db, 6, 1 / 55 * 60.0 * 1000 / (4000)½ * 1.0 * 1.0 * 0.9 * 0.50^1.5) = 6.0 in

-X Ld provided = *(Width - Wall) / 2 + Offset - Cover* = 3.50 * 12 / 2 + 0.0 - 9.0 / 2 - 2.0 = 14.5 in > 12.0 in OK

+X Ld provided = *(Width - Wall) / 2 - Offset - Cover* = 3.50 * 12 / 2 - 0.0 - 9.0 / 2 - 2.0 = 14.5 in > 12.0 in OK

Figure 77: ASDIP Bending Calculations

ASDIP was however very useful in calculating the bending that occurs both longitudinally along the wall and along the width of the footing. Steel rebar was utilized to provide the strength to resist the bending moment. For the top reinforcement we utilized 12 #6 bars and #4 bars spaced at 6” O.C. For the bottom reinforcement we utilized 12 #5 bars and #4 bars spaced at 6” O.C.

LOAD TRANSFER CALCULATIONS (Comb: Factored)

Area *A1 = wall L * t =* 9.0 * 12.0 = 108.0 in²

Sx = *wall L * t² / 6* = 12.0 * 9.0² / 6 = 162.0 in³

Bearing *Pbu = P / A1 + Mz / Sx* = 7.7 / 108.0 + 0.0 * 12 / 162.0 = 0.1 ksi

Min edge = *W / 2 - X-offset - wall t / 2* = 3.50 * 12 / 2 - 0.0 - 9.0 / 2 = 16.5 in

Area *A2 = Min [L * W, (wall L + 2 * Min edge) * (wall t + 2 * Min edge)]* ACI R22.8.3.2

A2 = Min [3.50 * 12 * 1.0 * 12, (9.0 + 2 * 16.5) * (12.0 + 2 * 16.5)] = 504.0 in²

Footing *ϕPnc = ϕ * 0.85 * f'c * Min [2, √(A2 / A1)] =* 0.65 * 0.85 * 4.0 * Min [2, √(504.0 / 108.0)] = 4.4 ksi

Footing *ϕPns = ϕ * As * Fy / A1 =* 0.65 * 0.62 * 60.0 / 108.0 = 0.2 ksi ACI 22.8.3.2

Footing bearing *ϕPn = ϕPnc + ϕPns =* 4.4 + 0.2 = 4.6 ksi > 0.1 ksi OK

Wall *ϕPnc = ϕ * 0.85 * f'c =* 0.65 * 0.85 * 3.0 = 1.7 ksi

Wall *ϕPns = ϕ * As * Fy / A1 =* 0.65 * 0.62 * 60.0 / 108.0 = 0.2 ksi ACI 22.8.3.2

Wall bearing *ϕPn = ϕPnc + ϕPns =* 1.7 + 0.2 = 1.9 ksi > 0.1 ksi OK

Shear friction *ϕVn = ϕ * As * Fy * μ =* 0.75 * 0.62 * 60.0 * 0.6 = 16.7 k/ft ACI Eq. (22.9.4.2)

Shear *Vu = Max (Vux, Vuz) =* Max (0.0, 0.0) = 0.0 k/ft < 16.7 k/ft OK

Straight *Ld req = Max (12.0, 3 / 40 * fy / (f'c)½ * Grade * Size / Cover * db * ratio)* ACI Eq. (25.4.2.4a)

Ld req = Max (12.0, 3 / 40 * 60.0 * 1000 / (3000)½ * 1.0 * 0.8 / 2.5 * 0.63 * 0.00) = 12.0 in

Hooked *Ldh = Max (8 db, 6, 1 / 55 * fy / (f'c)½ * Confining * Location * Concrete * db^1.5)* ACI 25.4.3

Ldh = Max (8 db, 6, 1 / 55 * 60.0 * 1000 / (4000)½ * 1.0 * 1.0 * 0.9 * 0.63^1.5) = 7.4 in

Dowel Ld provided = 36.0 in > 12.0 in OK

Dowel Ldh provided = *Footing thickness - Cover =* 18.00 - 2.5 = 15.5 in > 7.4 in OK

Wall f'c = 3.0 ksi Max. strain = 0.0030 Dowel fy = 60.0 ksi

Use #5 dowels @ 12.0 in each face , As = 0.62 in²

Wall As min = *0.0012 * L * t =* 0.0012 * 12.0 * 9.0 = 0.13 in² < 0.62 in² OK ACI 11.6.1

Figure 78: ASDIP Load Transfer Calculations

Since the footing is resisting a wall load. ASDIP requires that the dowel spacing from the wall be implemented into the design as the wall should be securely anchored to the footing. The dowel in the footing we implemented calls for #5 at 1 ft spacing at each face of the wall.

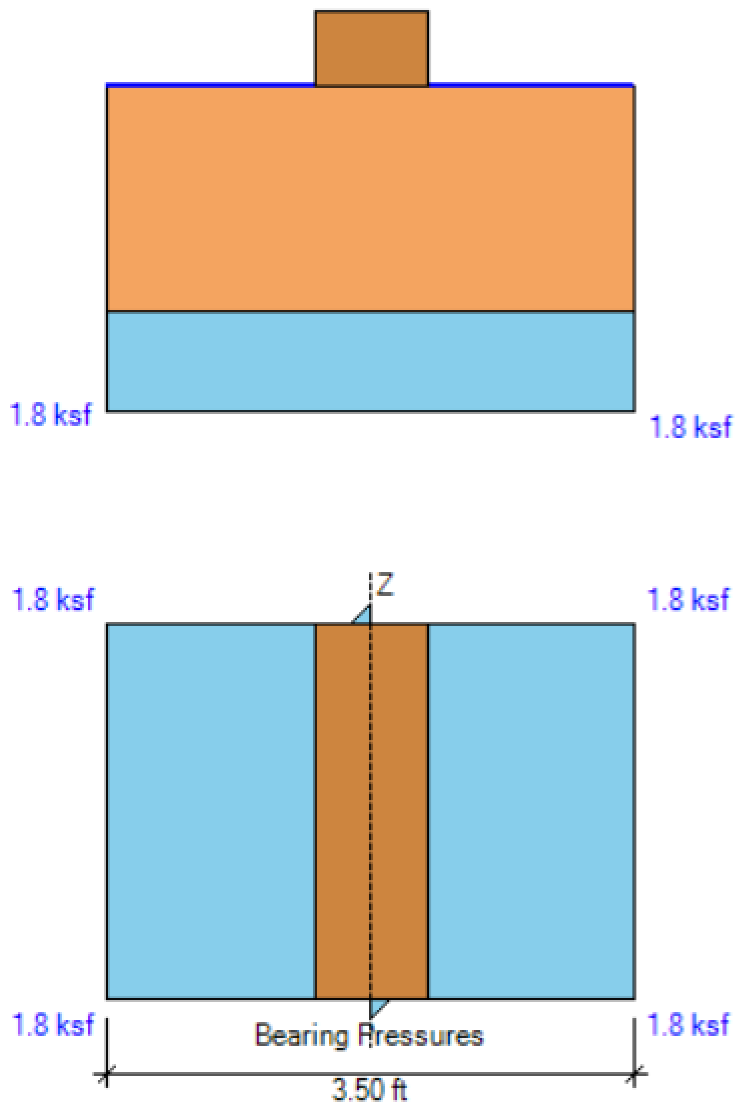


Figure 79: Continuous Footing Soil Bearing Pressure

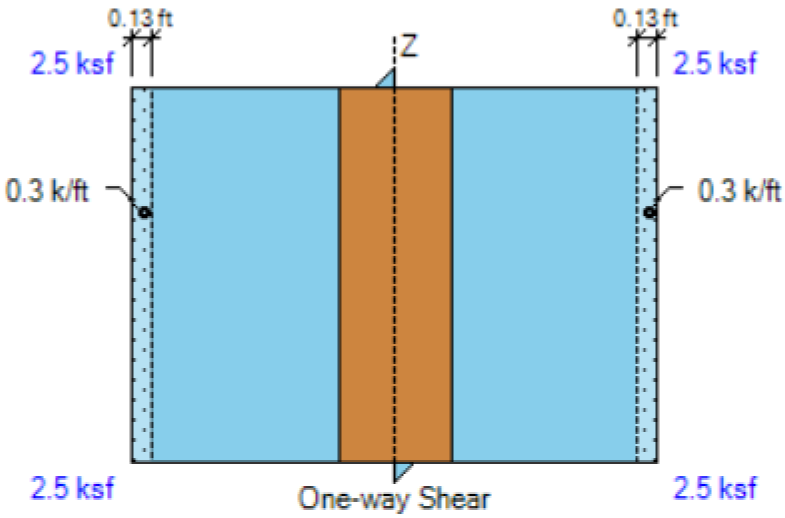


Figure 80: Continuous Footing Shear Diagram

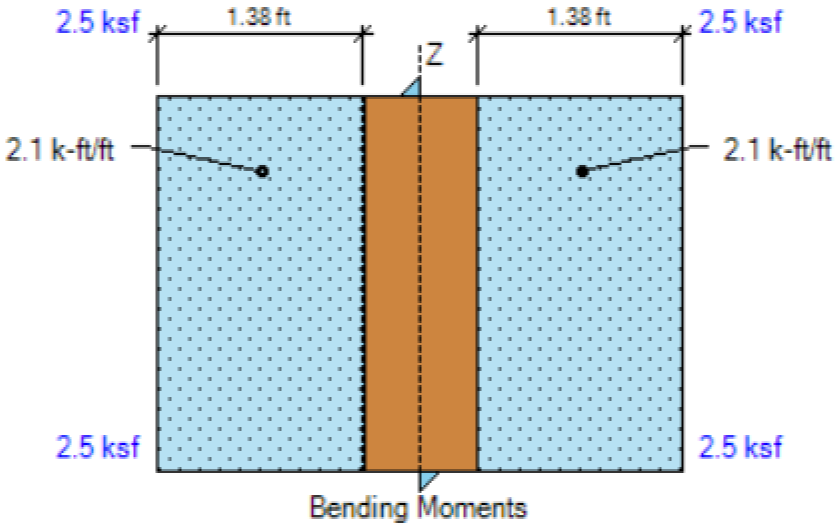


Figure 81: Continuous Footing Bending Diagram

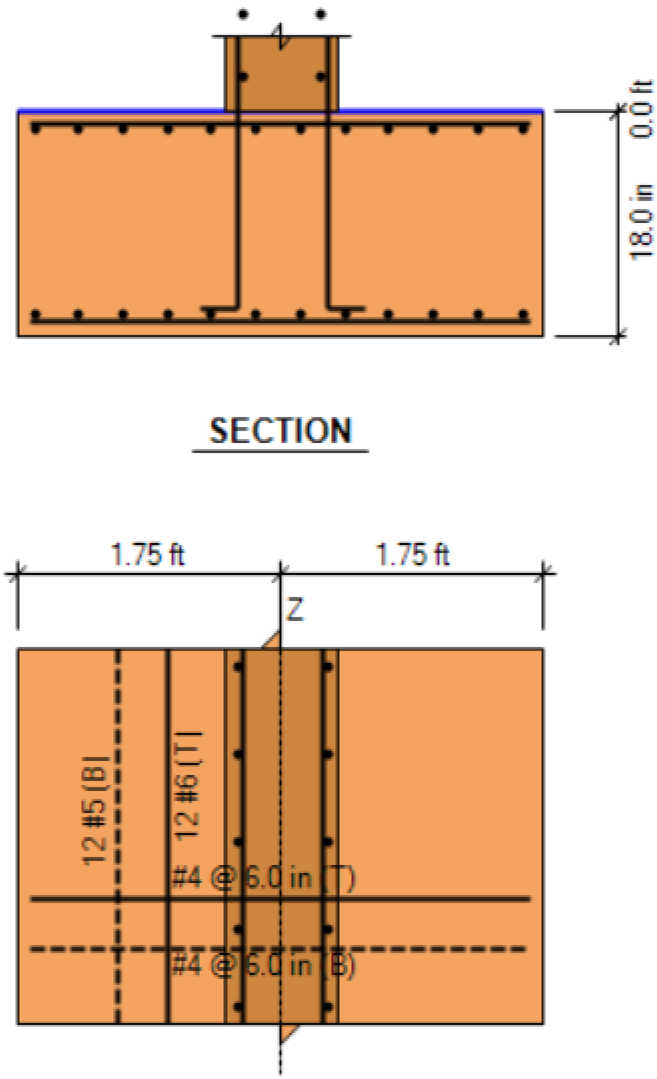


Figure 82: Continuous Footing Construction Sketches

Calculation of Square Footing Steel Utilizing SAFE by CSI

Safe by CSI was utilized to compare the results obtained by hand calculations through modeling each of the square footings and applying both dead load and live loads. We initially attempted to model our footings utilizing the ASDIP foundation software but were unable to due to restrictions imposed since we were only able to obtain a trial license.

The results obtained from the program Safe by CSI allowed us to calculate the deflection we expected to note based on our soil profile. Since we already had calculated the required footing dimensions the program was able to plot both shear and bending diagrams after factoring both the dead and live loads at 1.2 and 1.6 respectively. Results also obtained from the program calculated a shear check.

We did note however that the shear values were extremely low for some footings. However at significantly higher loads that other footings were under the values are in line with what we expect as we must be able to satisfy three criterias to ensure the footings meet both one-way shear, two-way shear, and flexure; some of the demand to capacity ratios will be lower in comparison to that of flexure and two-way shear.

Footing 1

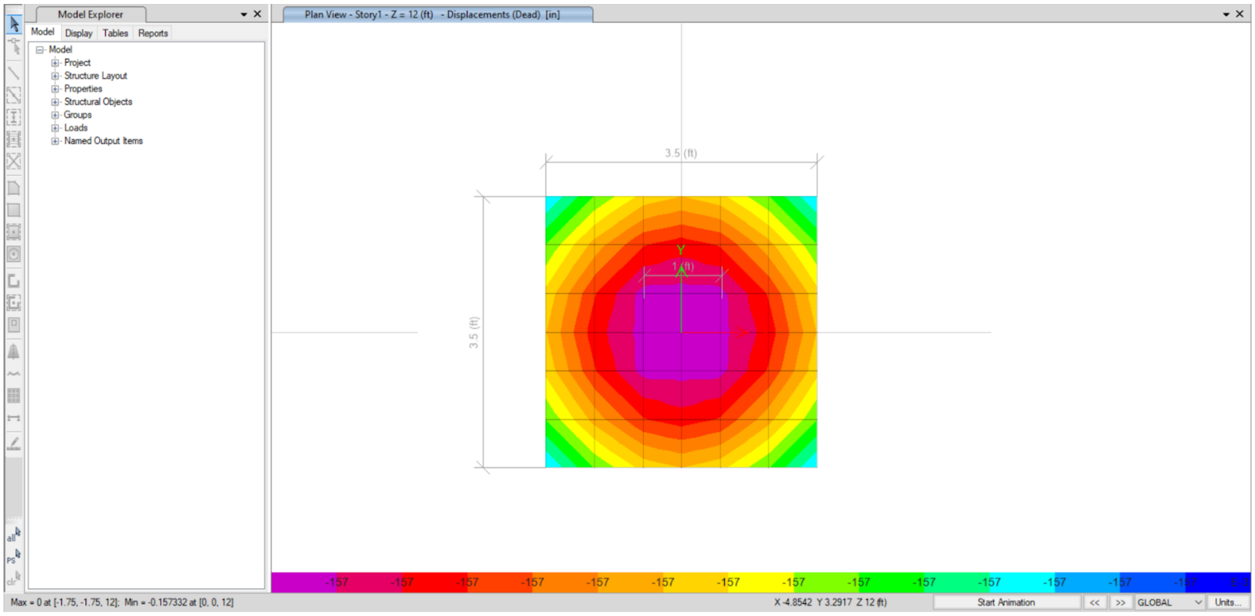


Figure 83: Footing 1 Deflection

The Deflection in the footing was calculated to be .157 inches. This deflection we found to be well within our allowable settlement of 0.5 inch per footing. This is accounting for the factored loads of a dead load of 24.375 kips and live load of 8.126 kips

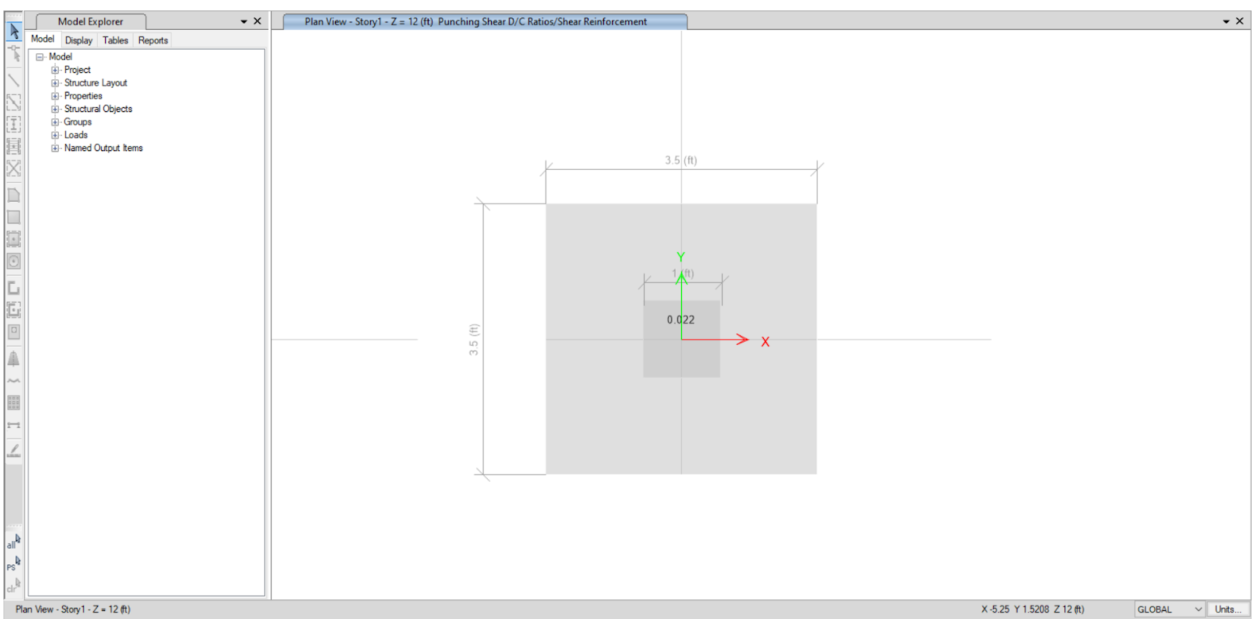


Figure 84: Footing 1 Shear Check

The program also ran a shear check and calculated a demand to capacity ratio of .02. We believe this value seemed a little low as we obtained a demand to capacity ratio from both one way shear and two-way shear of .14 and 0.2 respectively.

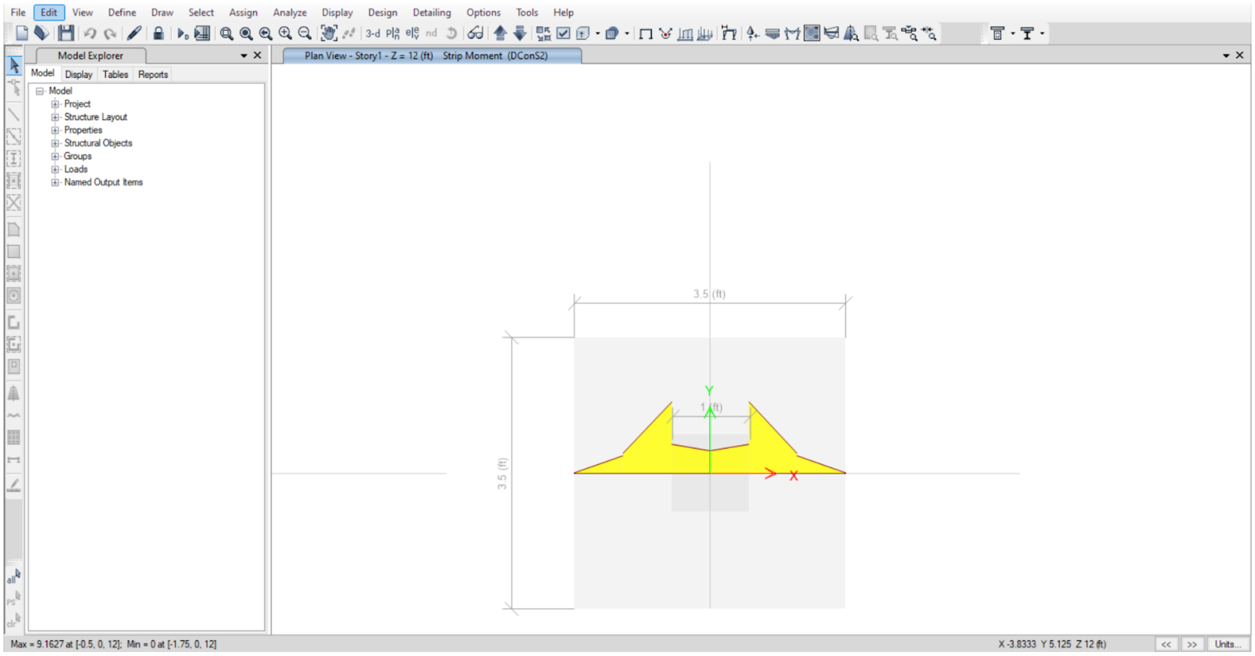


Figure 85: Footing 1 Bending

The calculated bending moment for our footing through safe was found to be 9.2 k-ft. This value obtained is significantly close to the value we calculated through hand calculations which we found to be 9.43 k-ft.

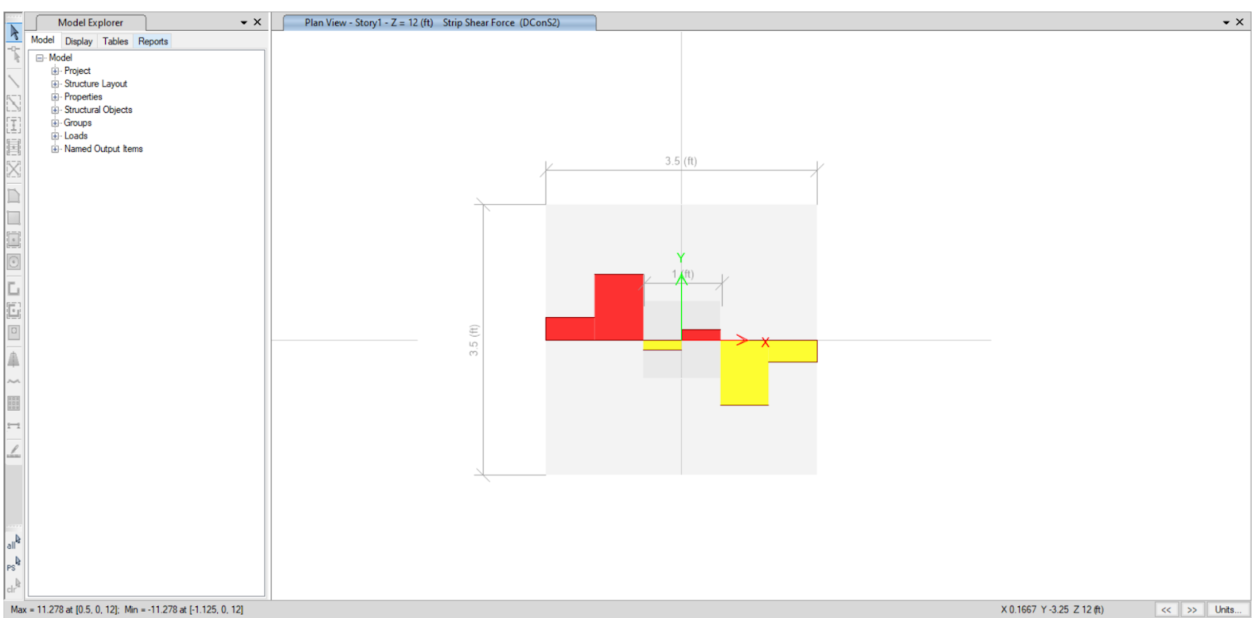


Figure 86: Footing 1 Shear

The value we obtained from safe for footing number 1 was 11.2 kips. This value was significantly higher than our one-way shear we obtained through hand calculations of 5.53 kips.

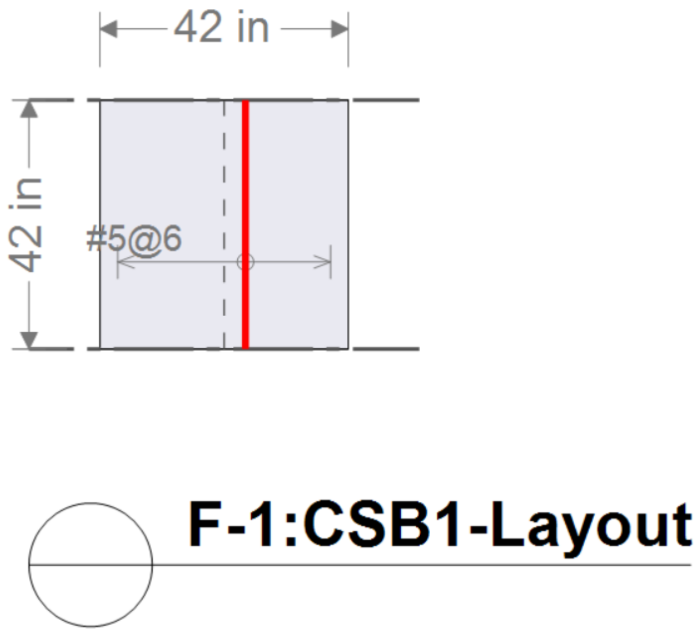


Figure 87: Footing 1 Steel Layout

After running the program in Safe we were able to find the minimum amount of steel required to get the bending moment and shear loads satisfied. Different rebar types called for different spacing. I decided to choose the same rebar numbers to be consistent. After running the analysis we were obtaining the same amount of required rebar as our hand calcs. This result makes sense because the bending moments obtained from hand calculations were closely the same as those obtained from the program SAFE.

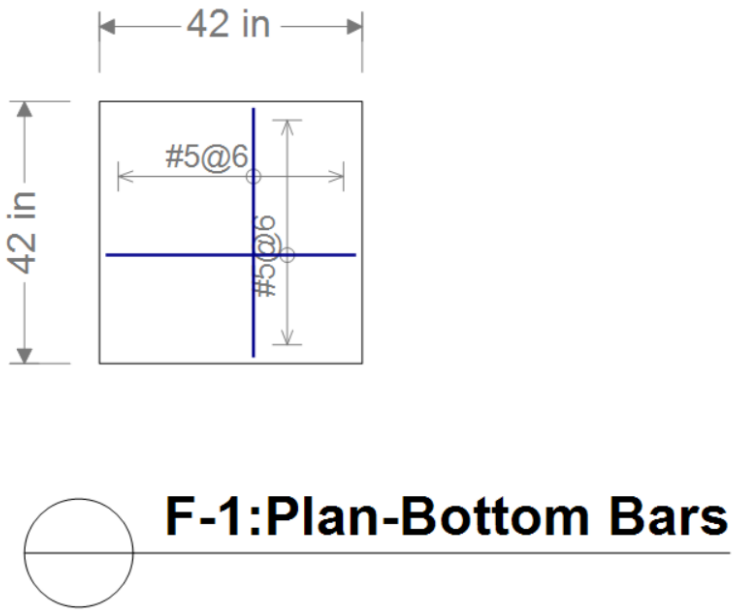


Figure 88: Footing 1 Steel Layout 2

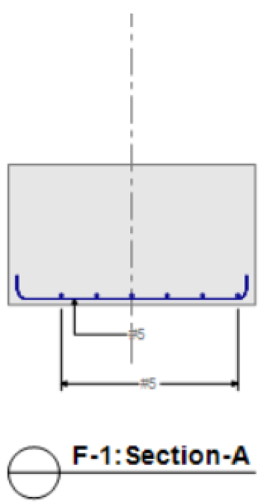


Figure 89: Footing 1 Cross Section

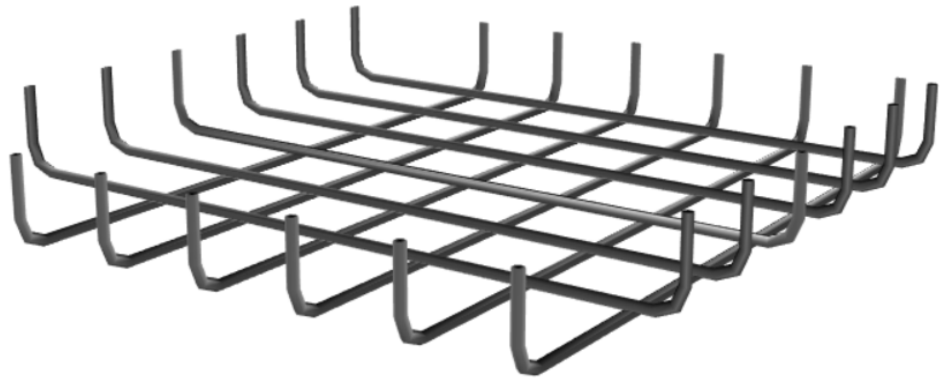


Figure 90: Footing 1 3D- Steel Layout

Footing 2

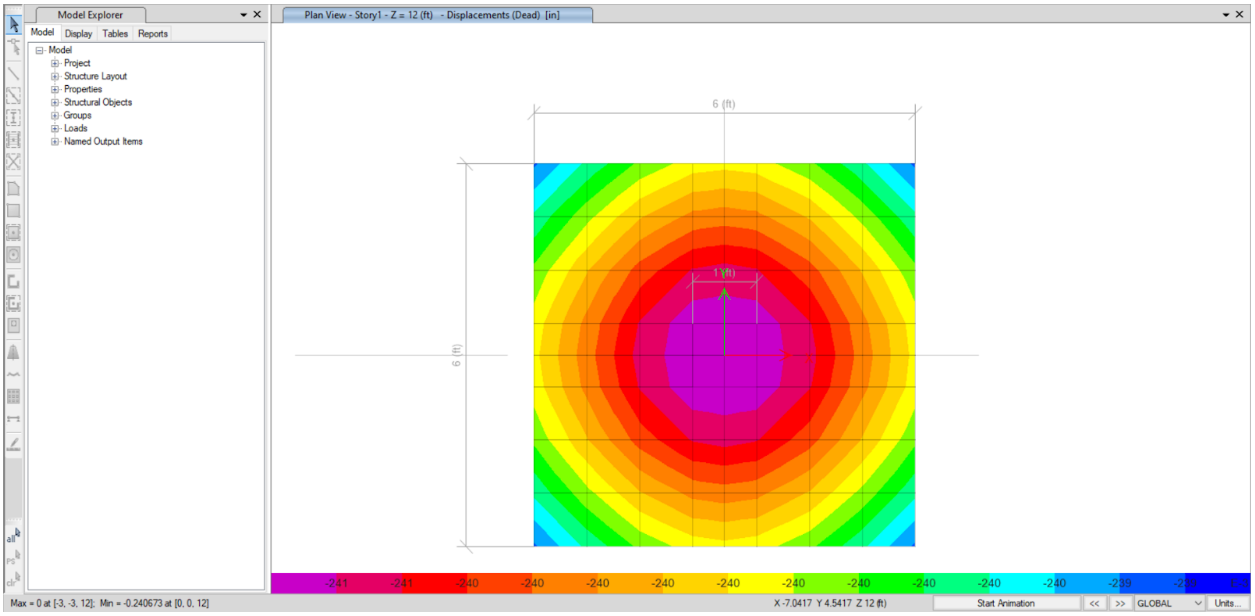


Figure 91: Footing 2 Deflection

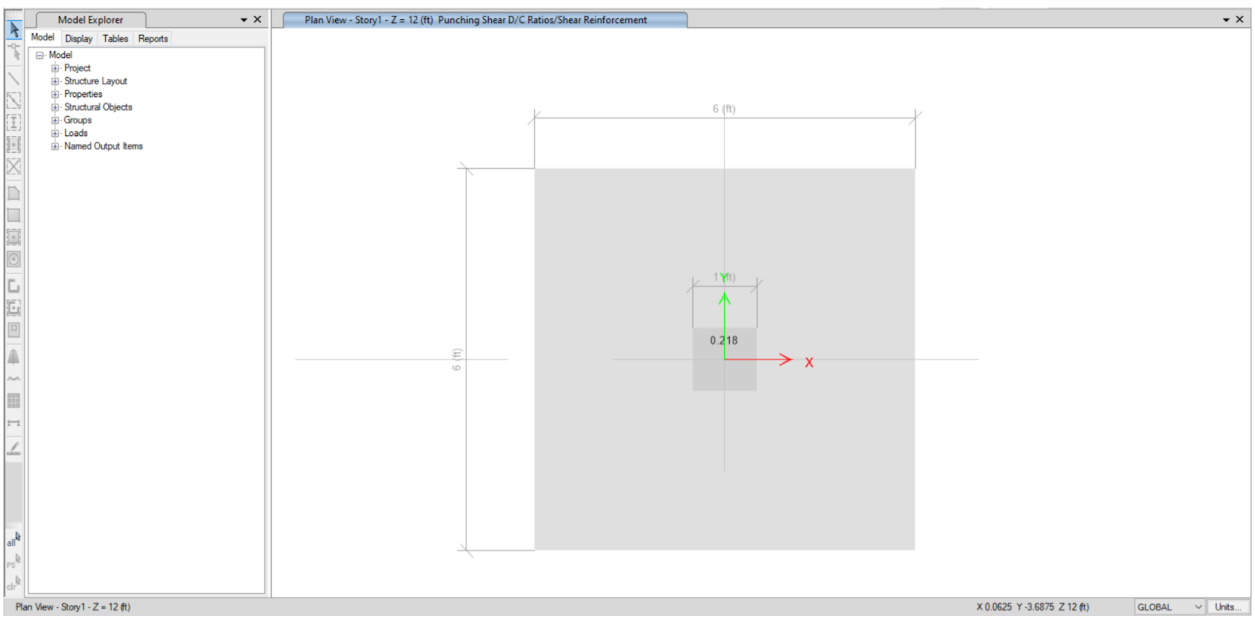


Figure 92: Footing 2 Shear Check

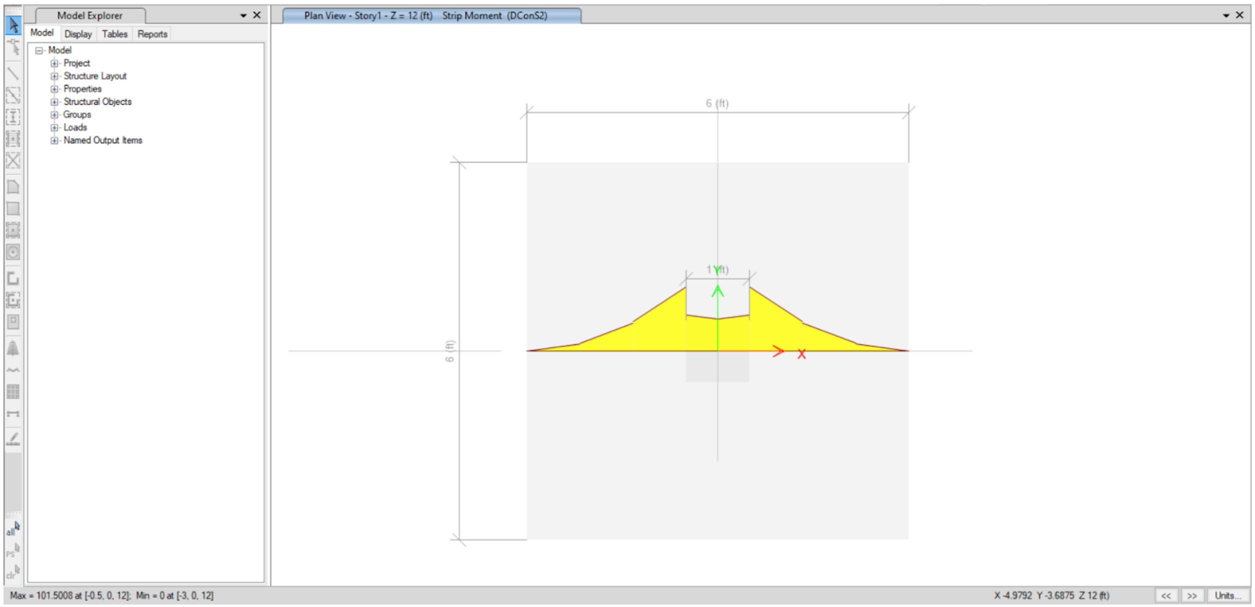


Figure 93: Footing 2 Bending Diagram

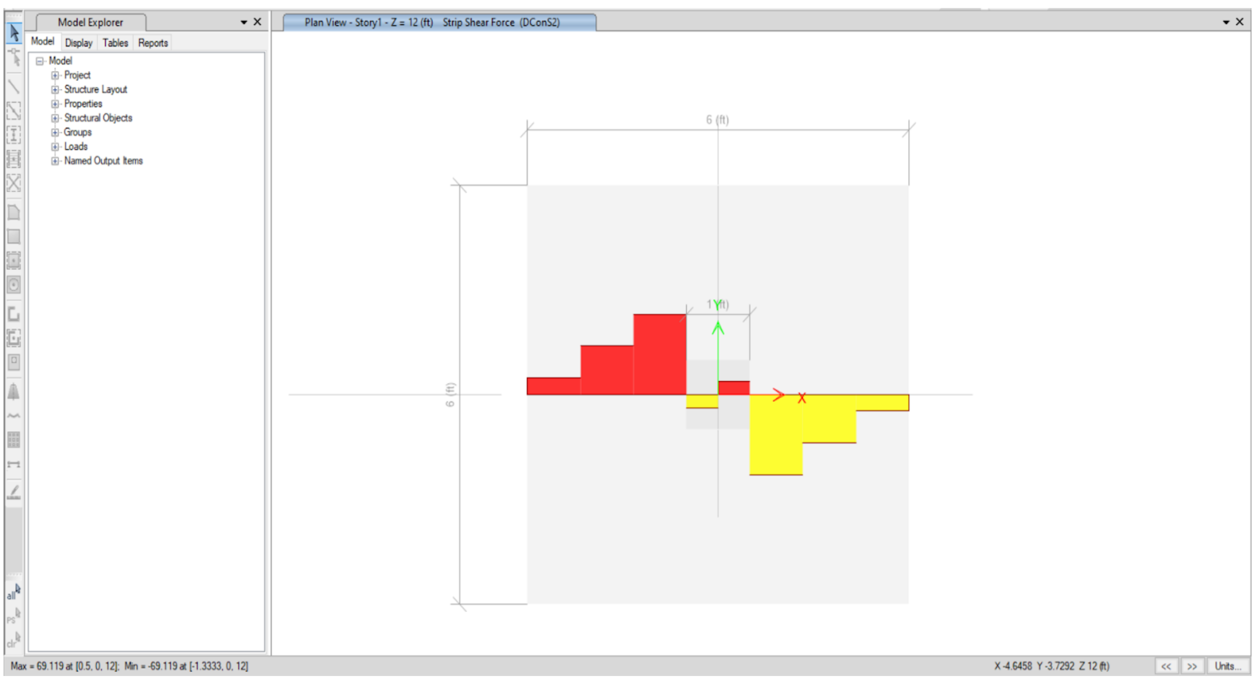


Figure 94: Footing 2 Shear Diagram

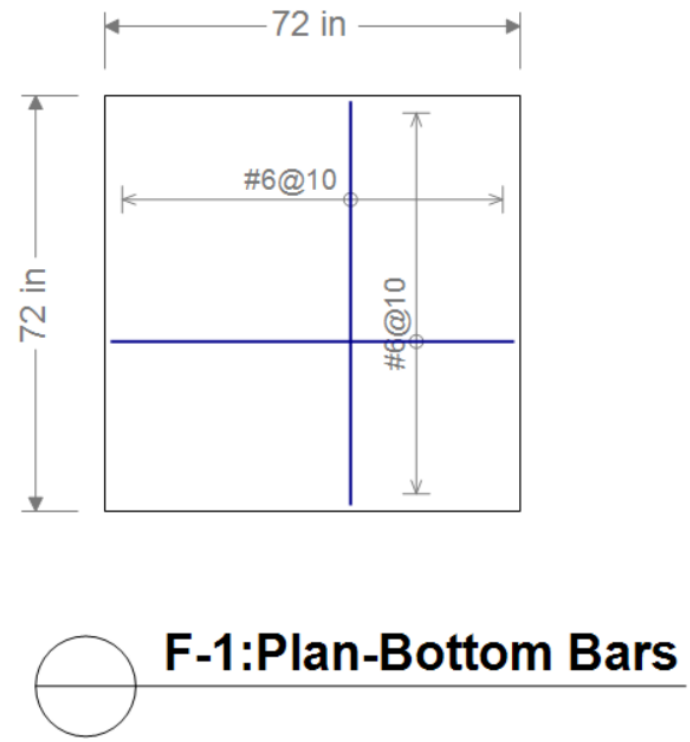


Figure 95: Footing 2 Steel Layout

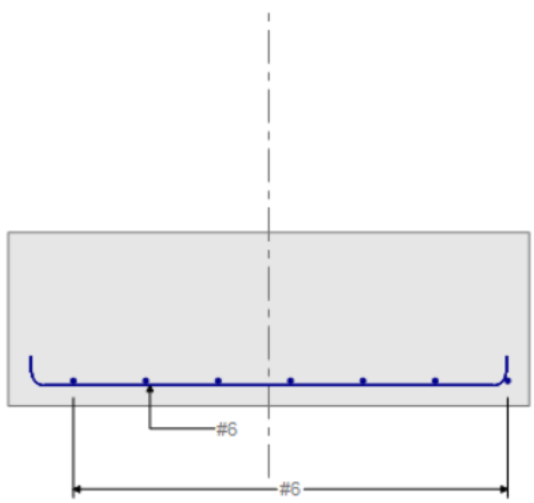


Figure 96: Footing 2 Cross-Section

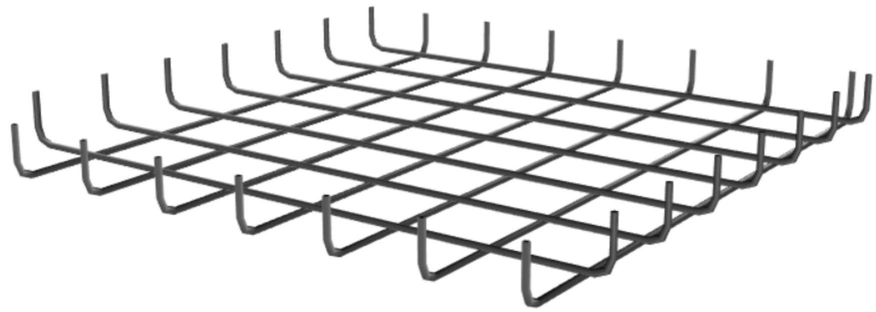


Figure 97: Footing 2; 3D-Steel Layout

Footing 3

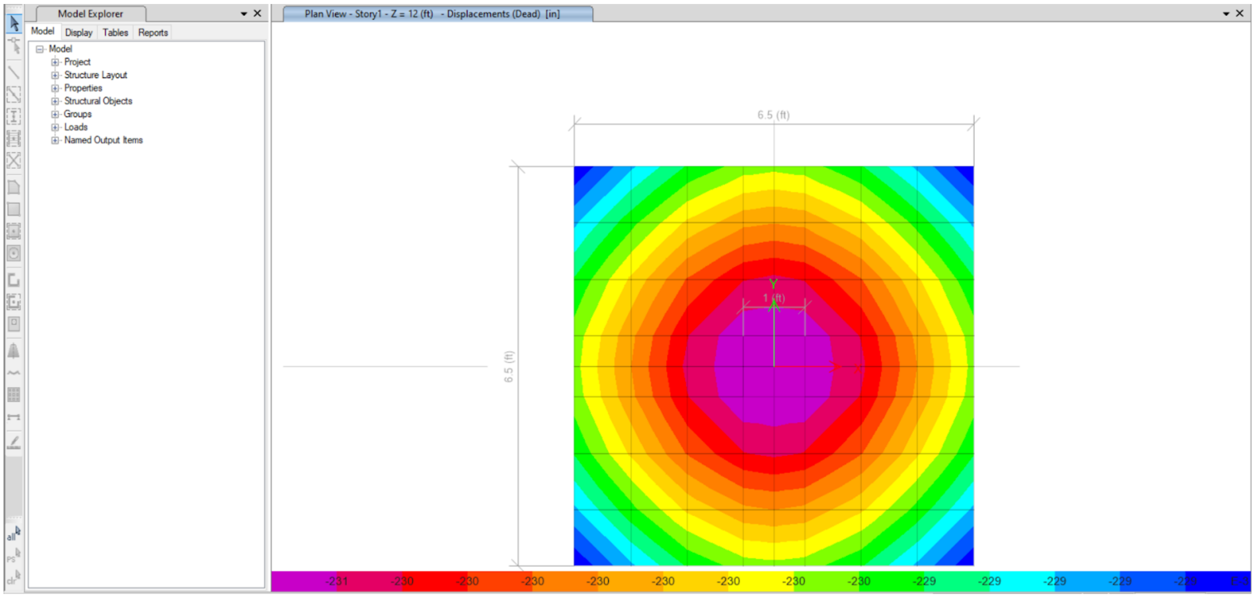


Figure 98: Footing 3 Deflection

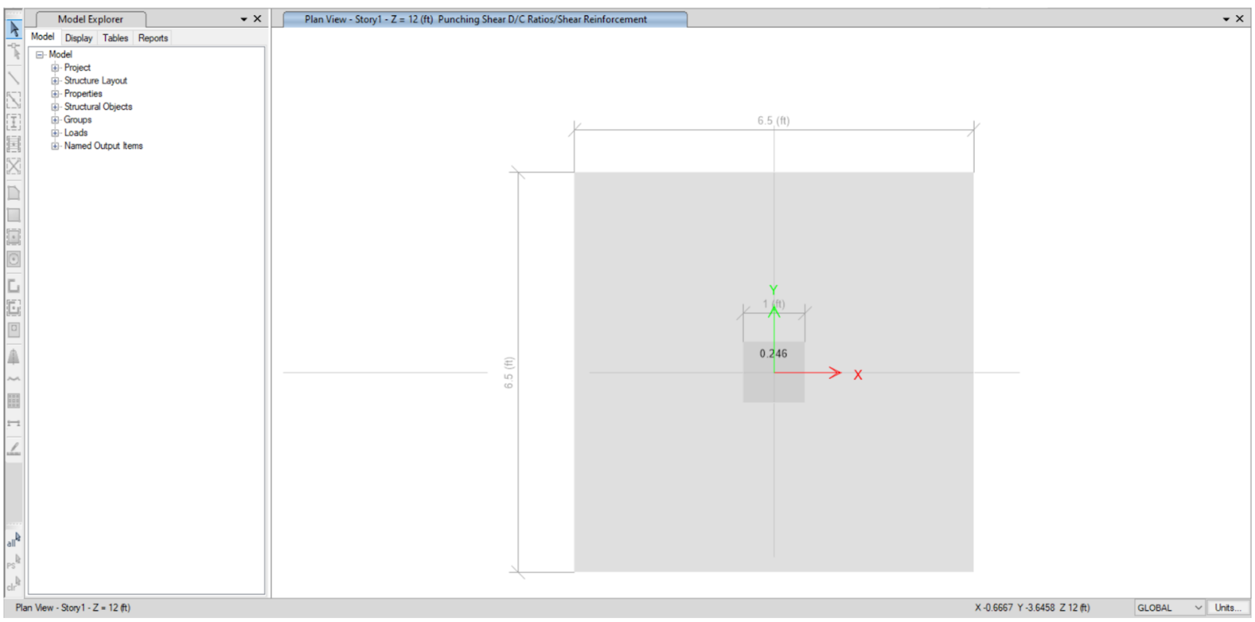


Figure 99: Footing 3 Shear Check

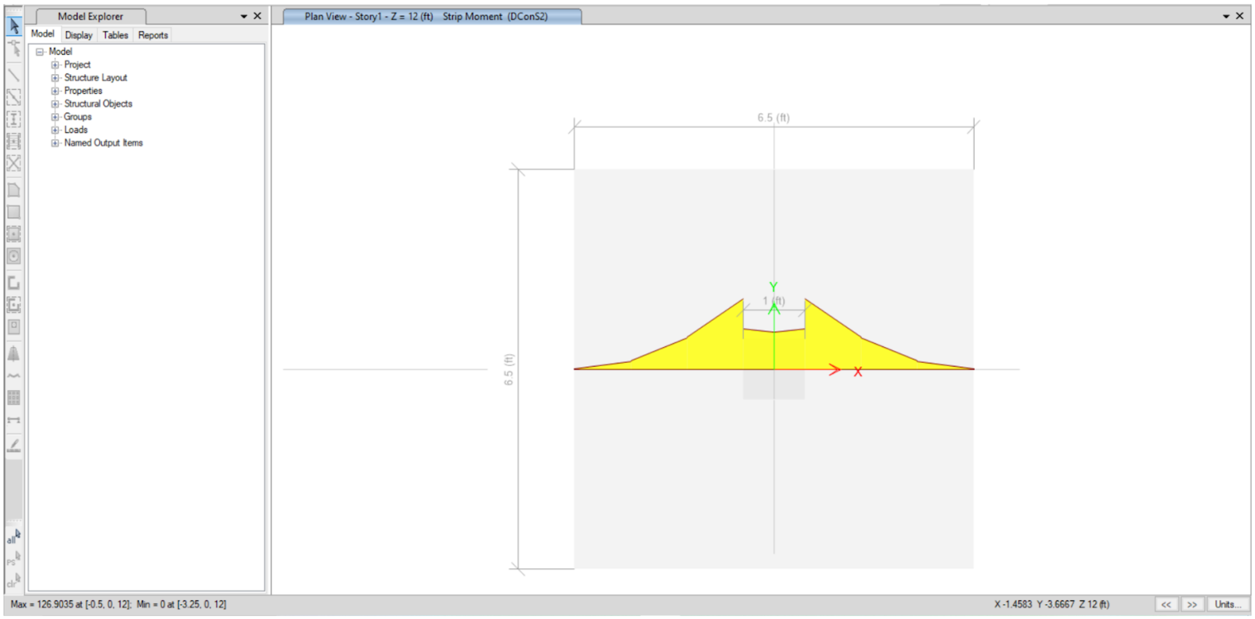


Figure 100: Footing 3 Bending Diagram

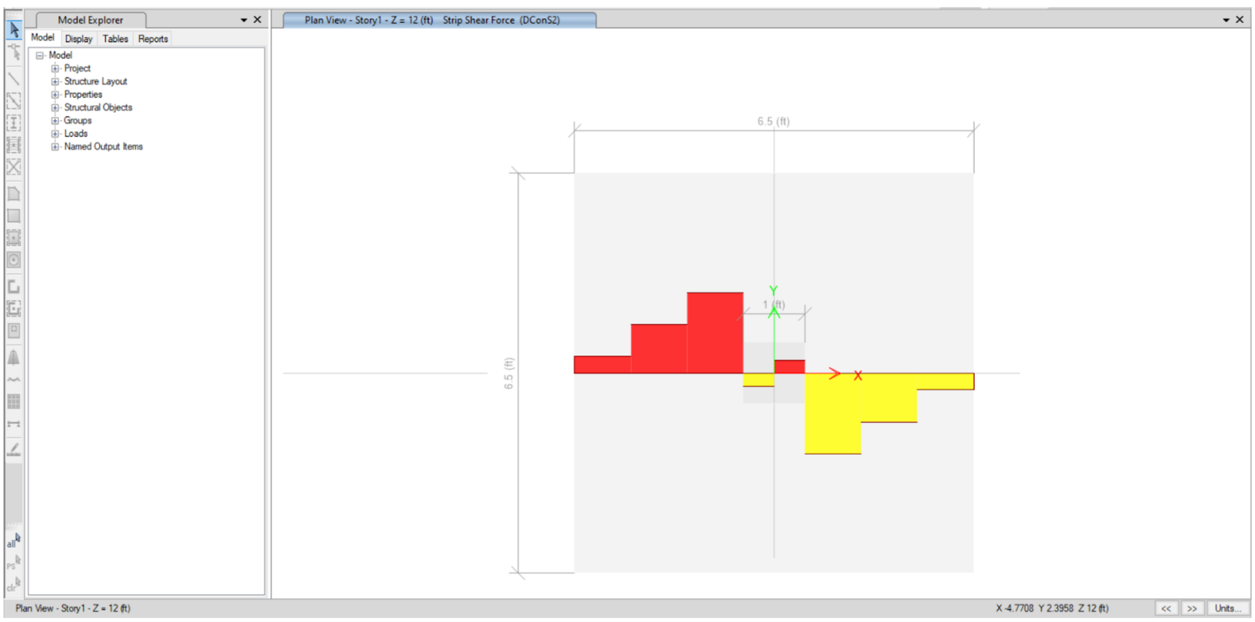


Figure 101: Footing 3 Shear Diagram

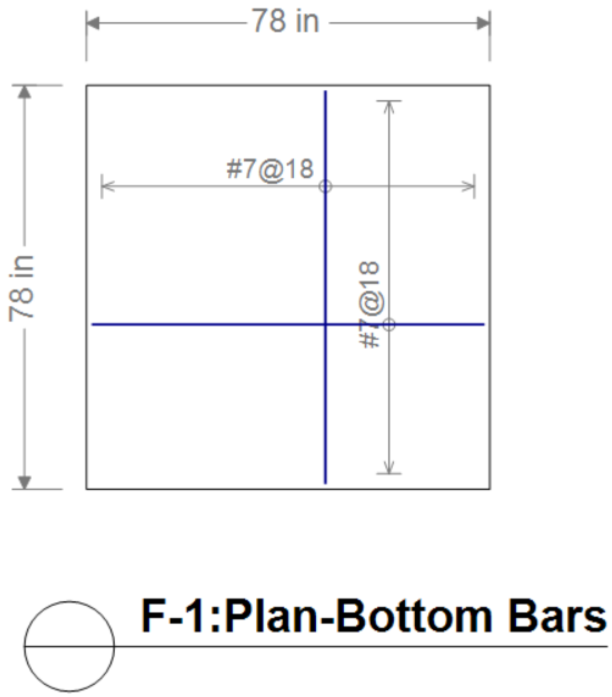


Figure 102: Footing 3 Steel Layout

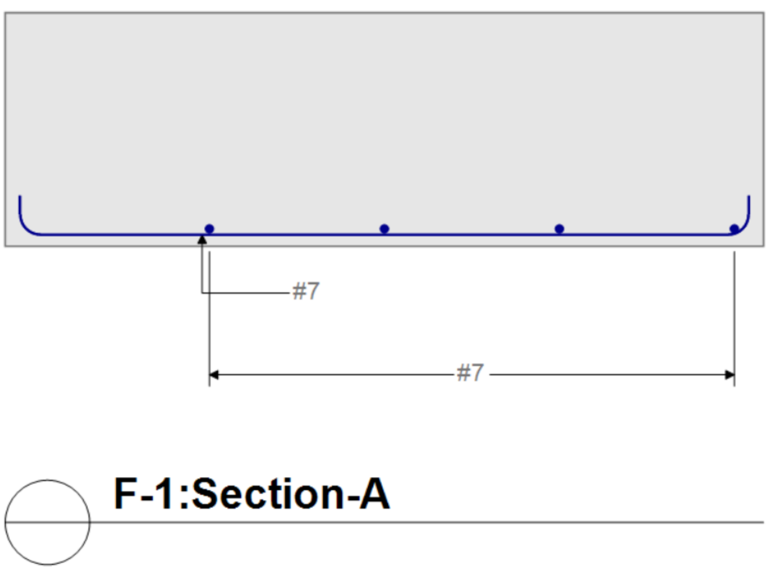


Figure 103: Footing 3 Cross Section

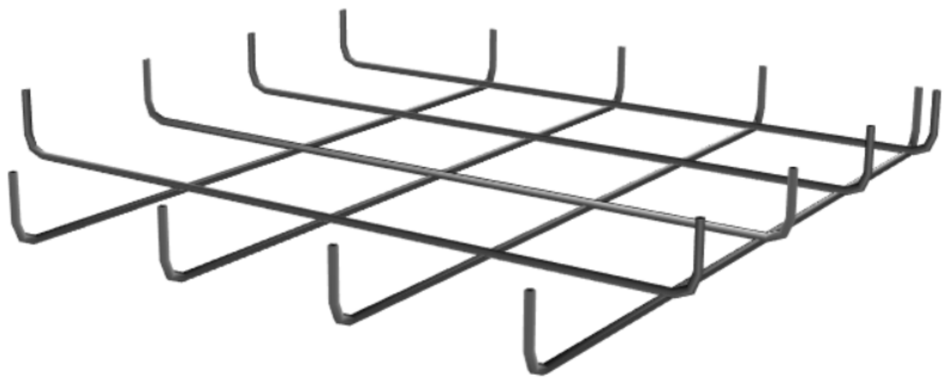


Figure 104: Footing 3; 3D Steel Layout

Footing 4

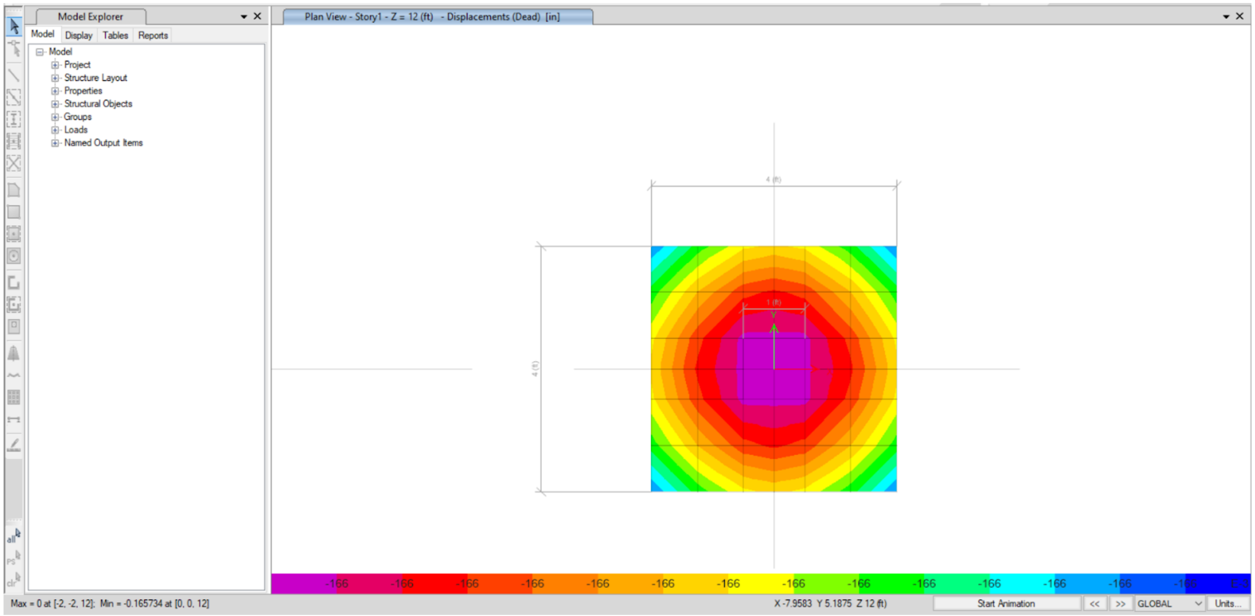


Figure 105: Footing 4 Deflection

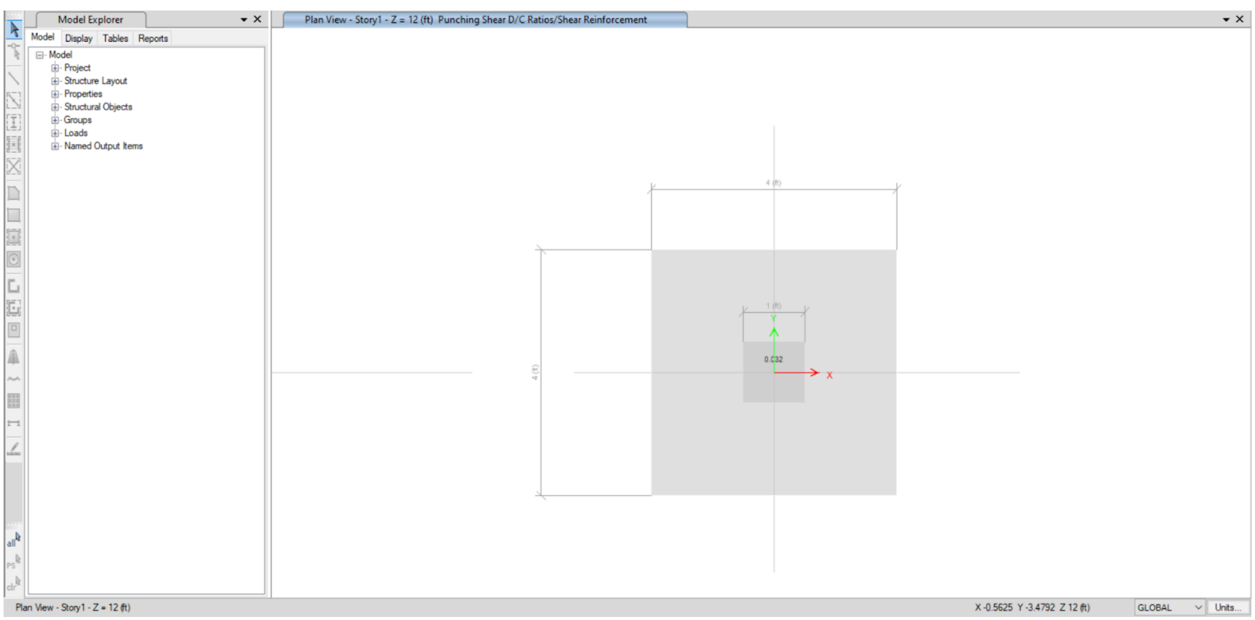


Figure 106: Footing 4 Shear Check

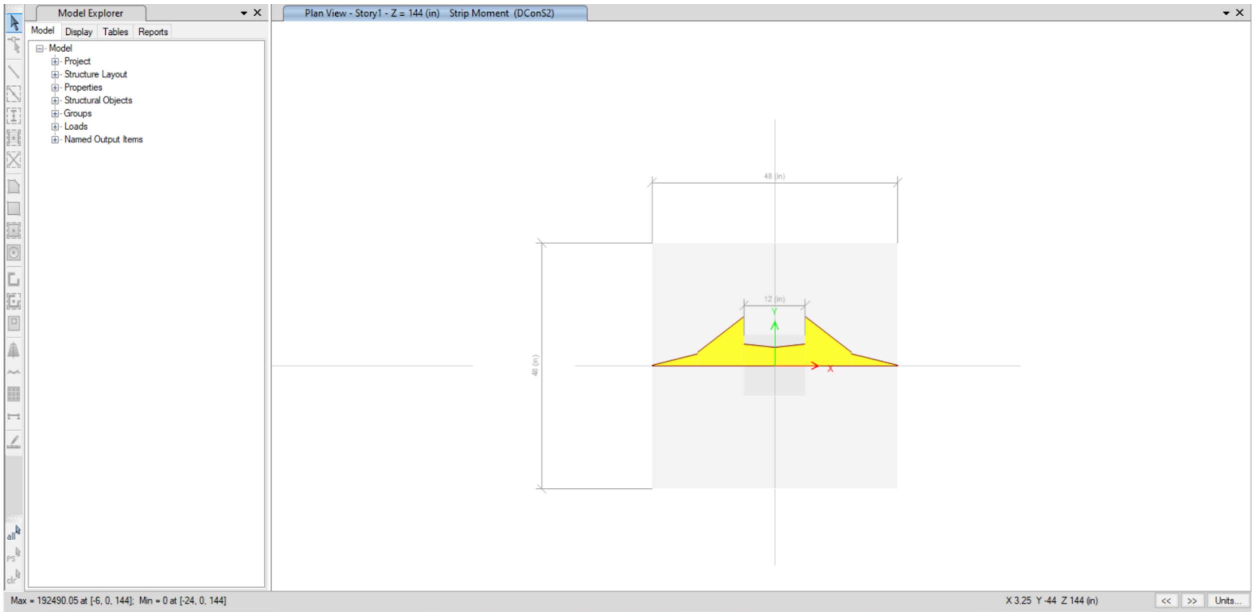


Figure 107: Footing 4 Bending Diagram

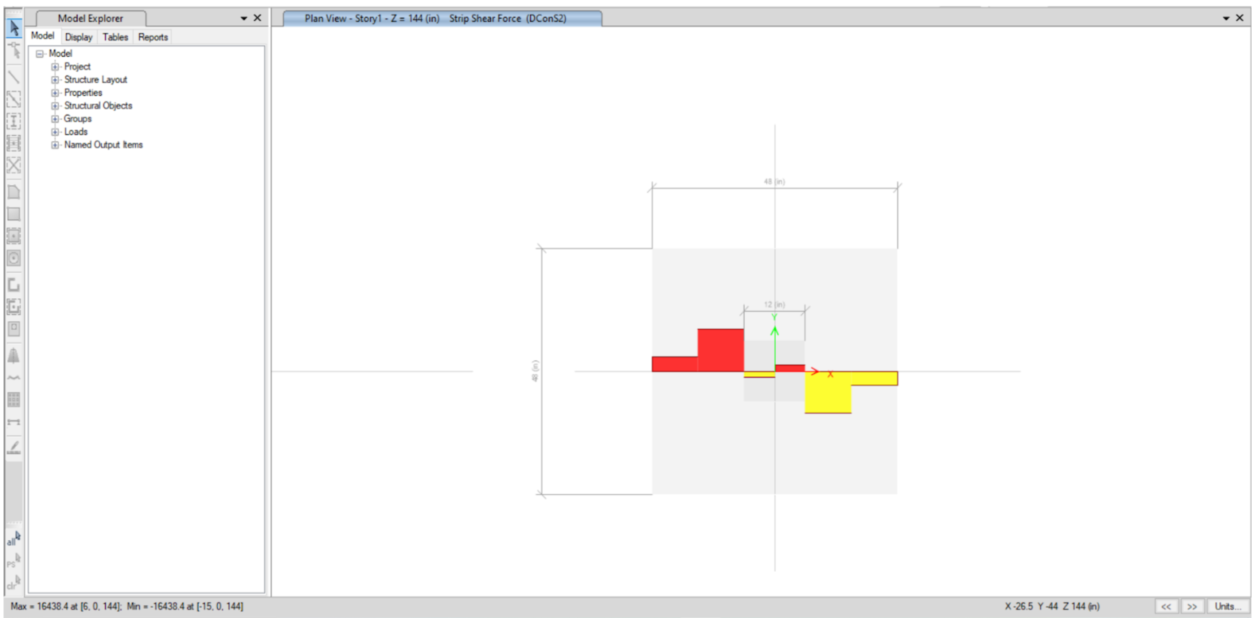


Figure 108: Footing 4 Shear Diagram

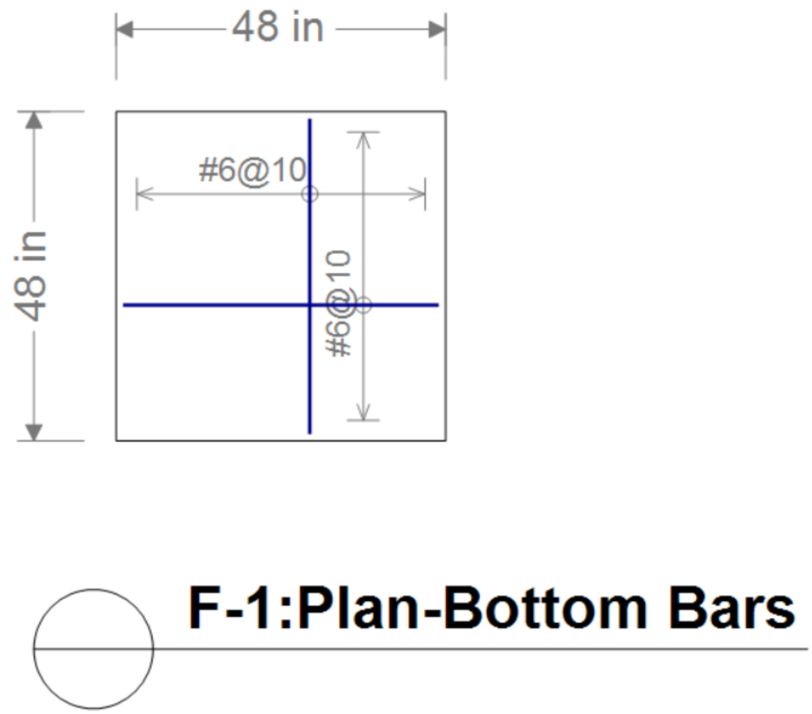


Figure 109: Footing 4 Steel Layout

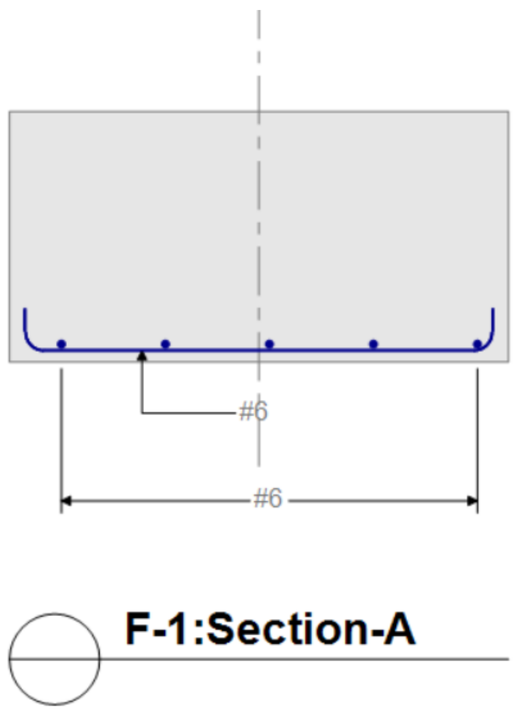


Figure 110: Footing 4 Cross-Section

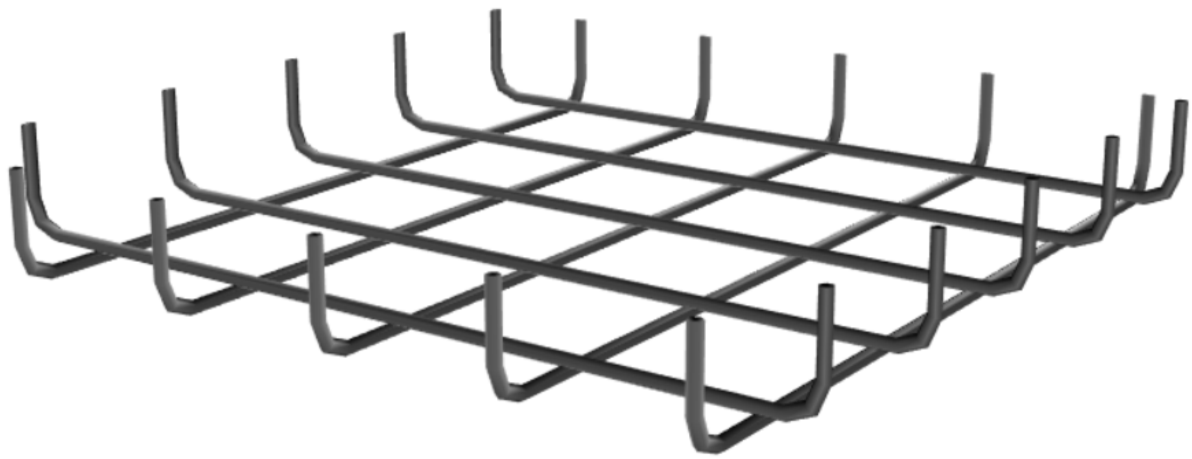


Figure 111: Footing 4; 3D Steel Layout

Footing 5

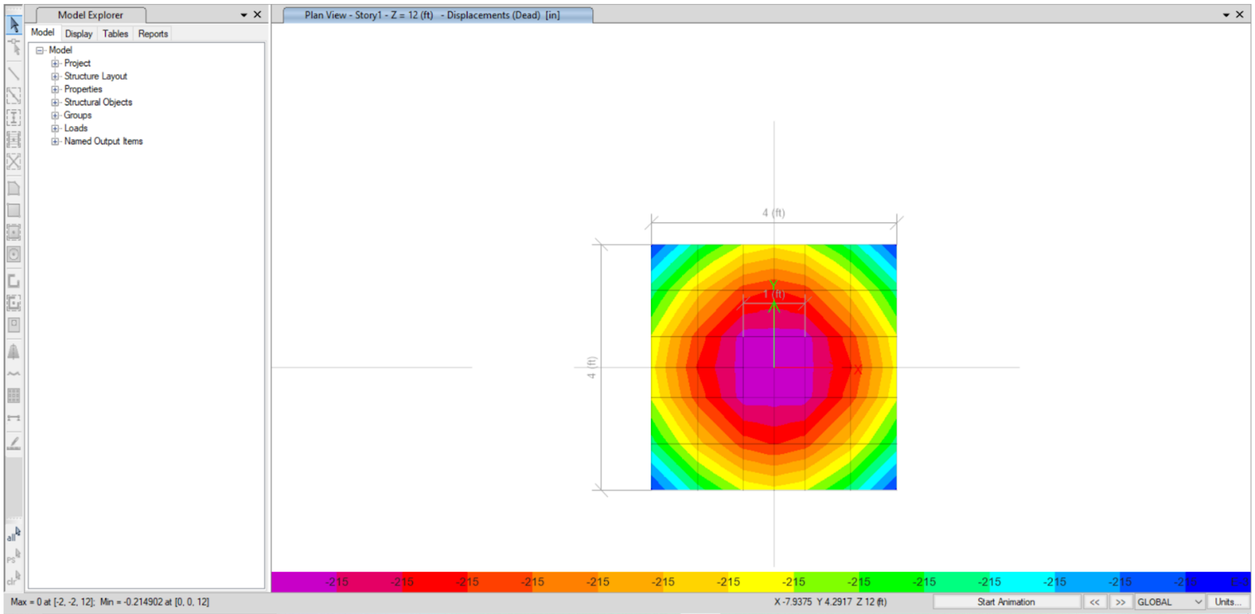


Figure 112: Footing 5 Deflection

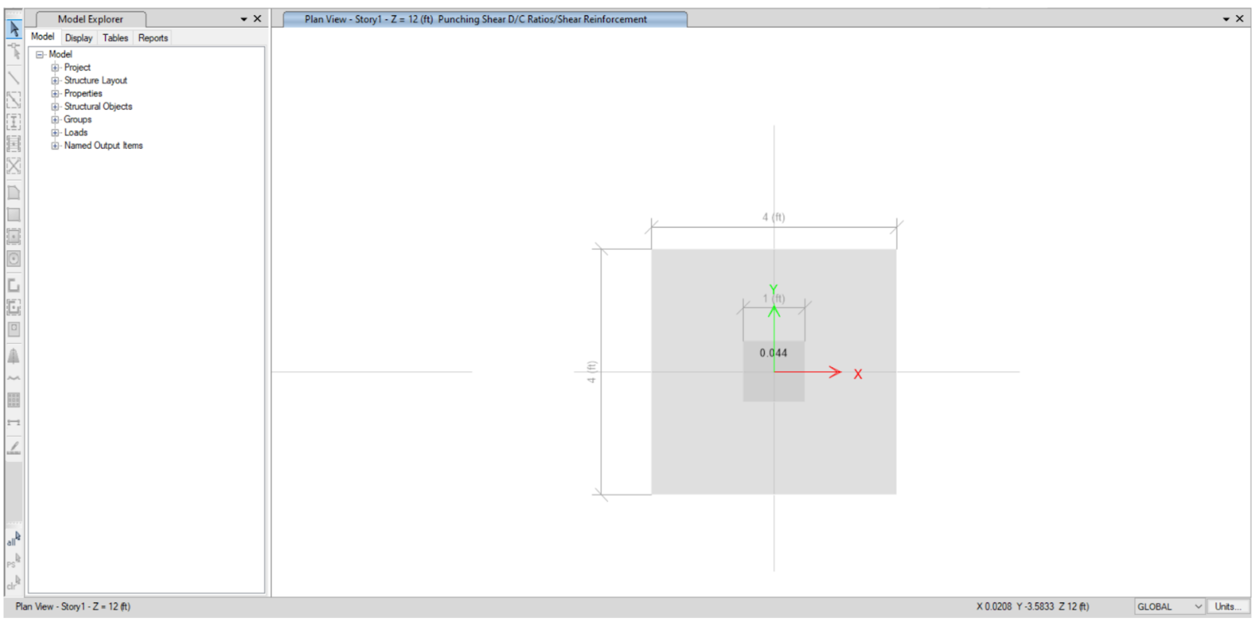


Figure 113: Footing 5 Shear Check

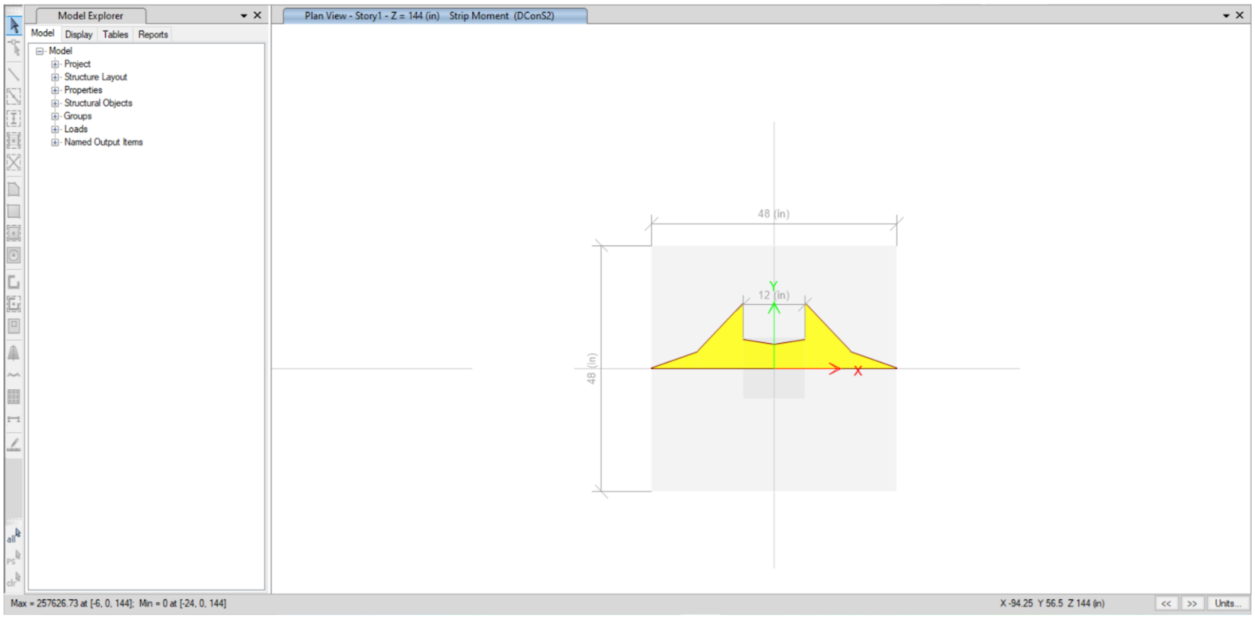


Figure 114: Footing 5 Bending Diagram

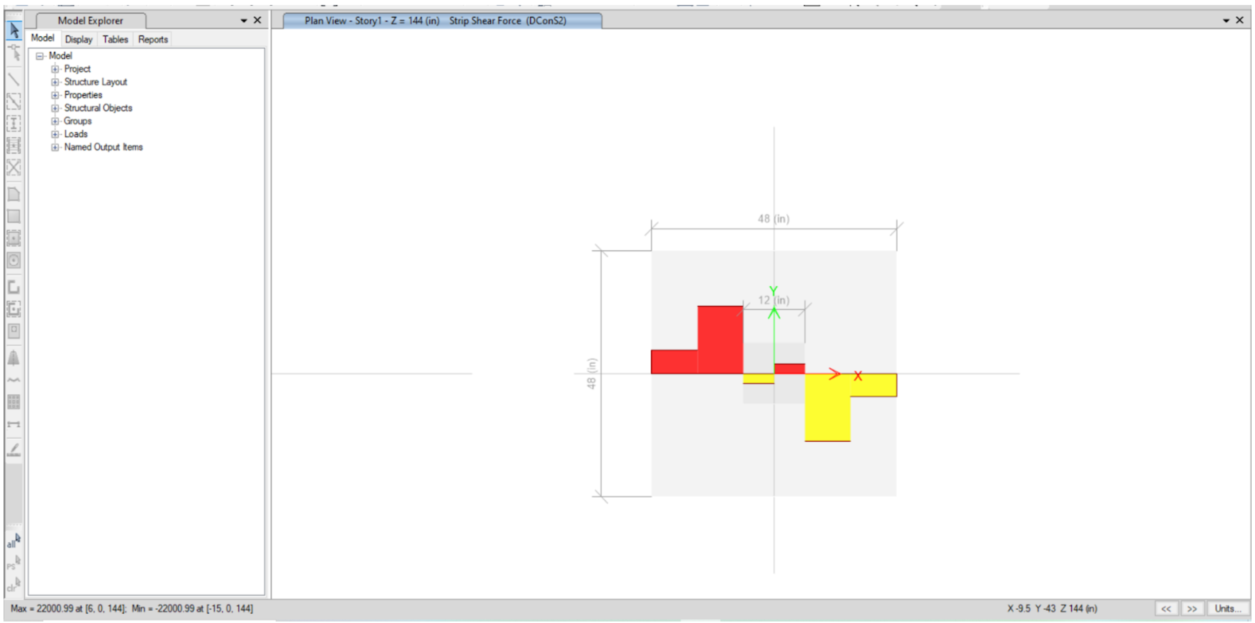


Figure 115: Footing 5 Shear Diagram

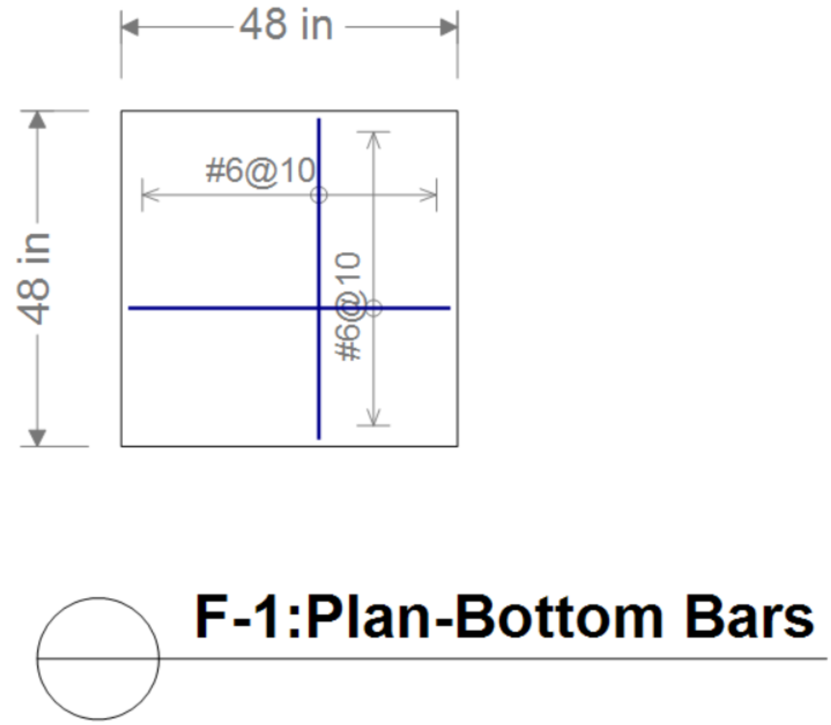


Figure 116: Footing 5 Steel Layout

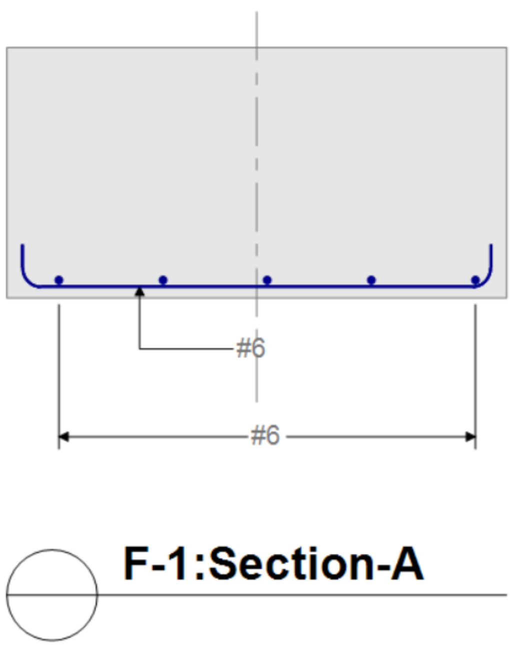


Figure 117: Footing 5 Cross Section

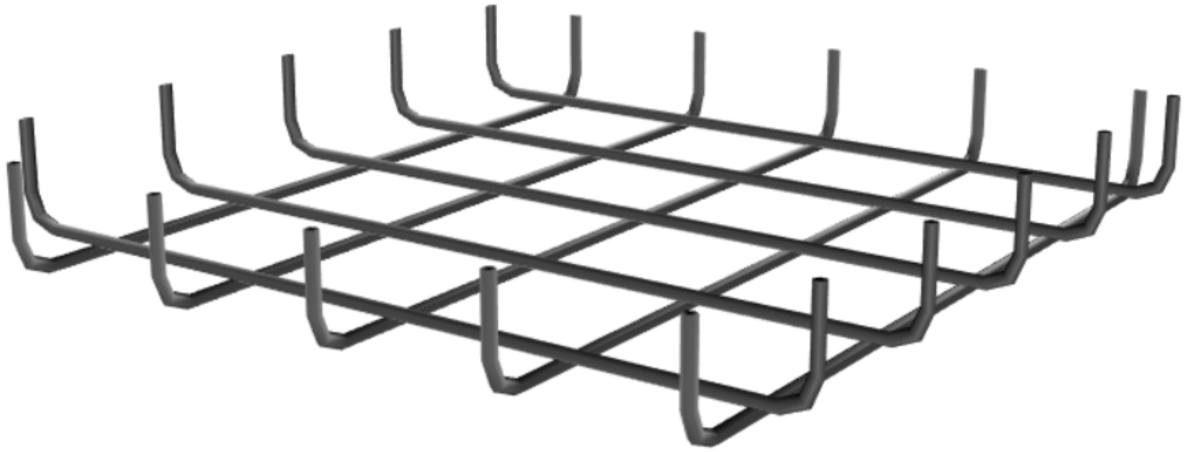


Figure 118: Footing 5; 3D Steel Layout

Footing 6

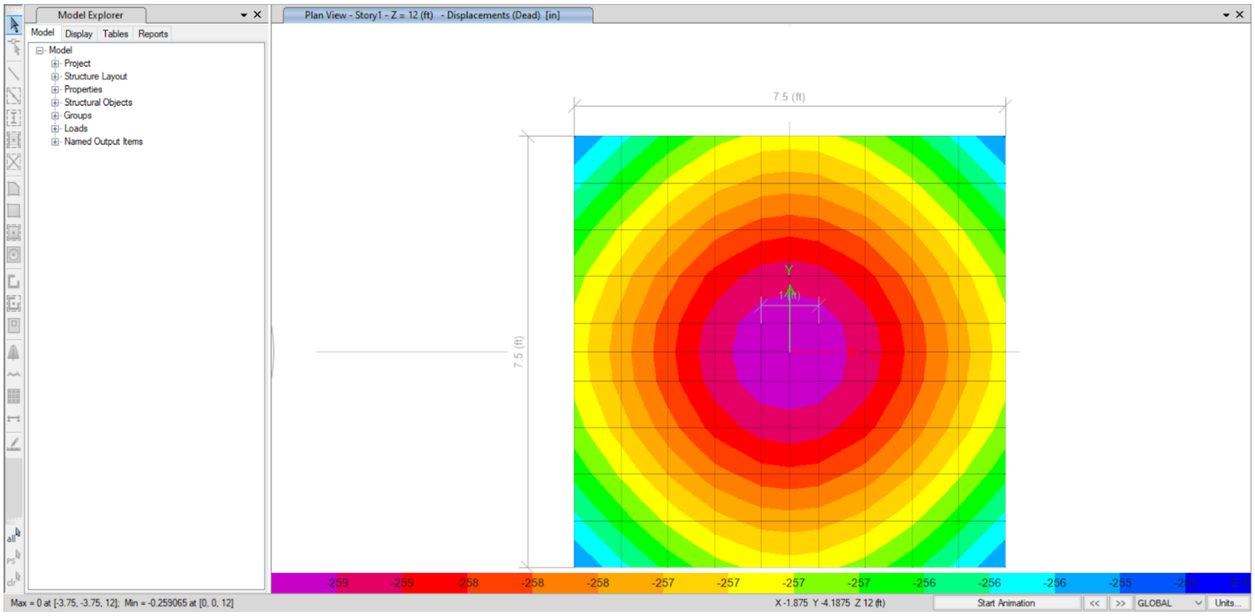


Figure 119: Footing 6 Deflection

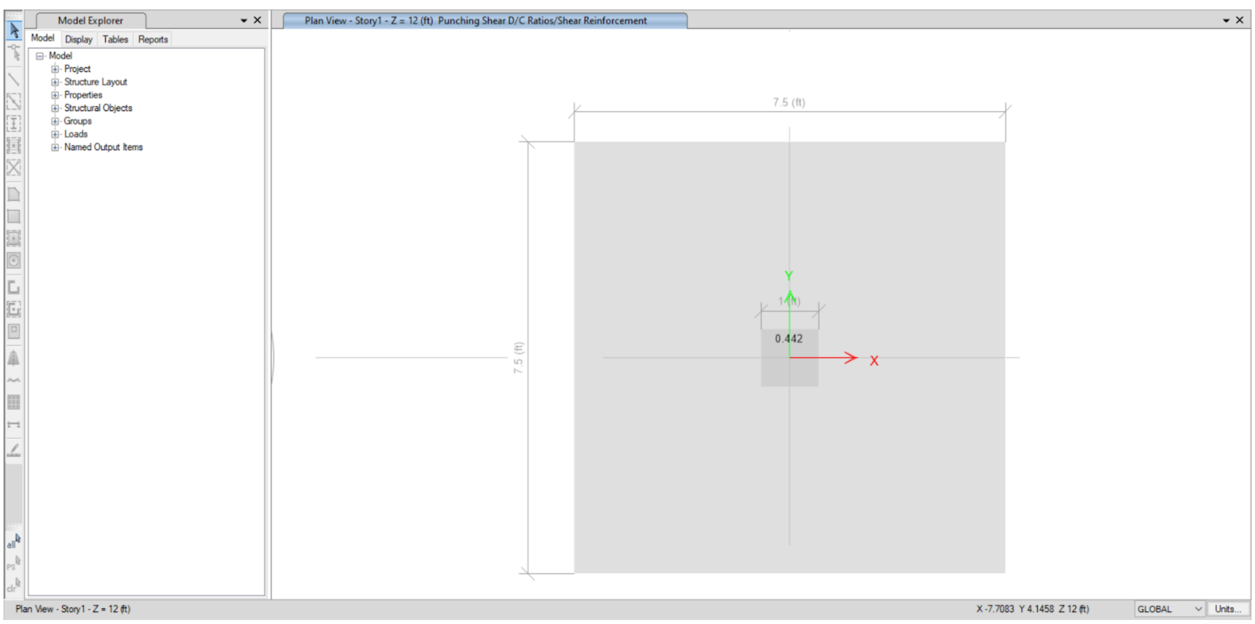


Figure 120: Footing 6 Shear Check

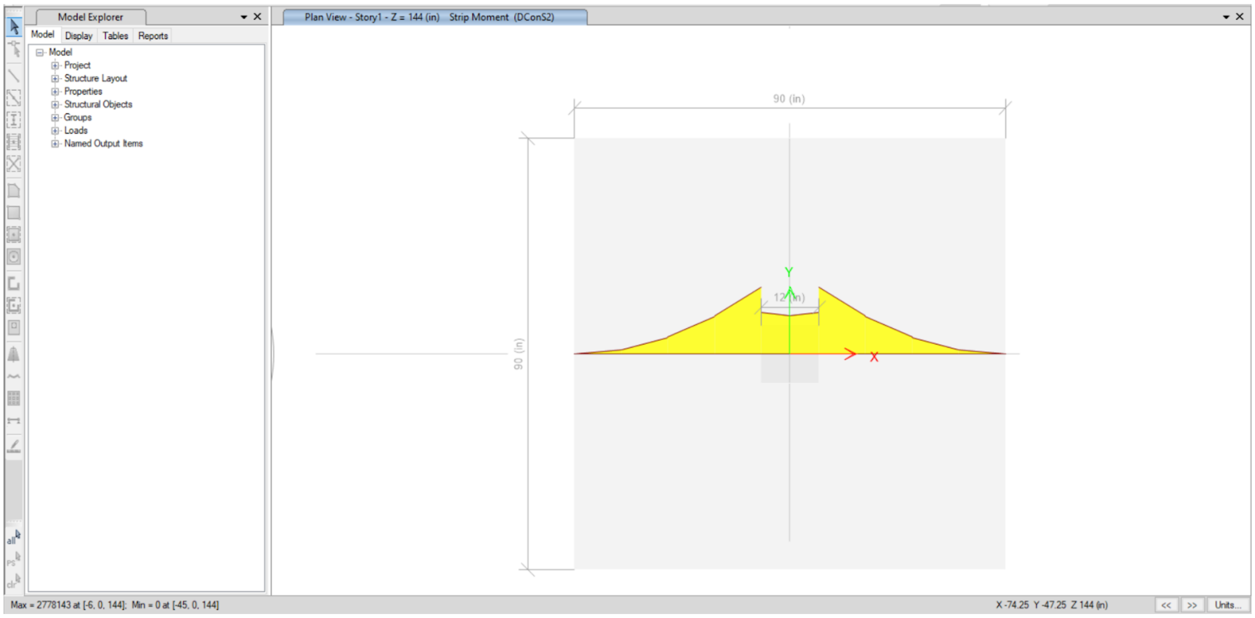


Figure 121: Footing 6 Bending Diagram

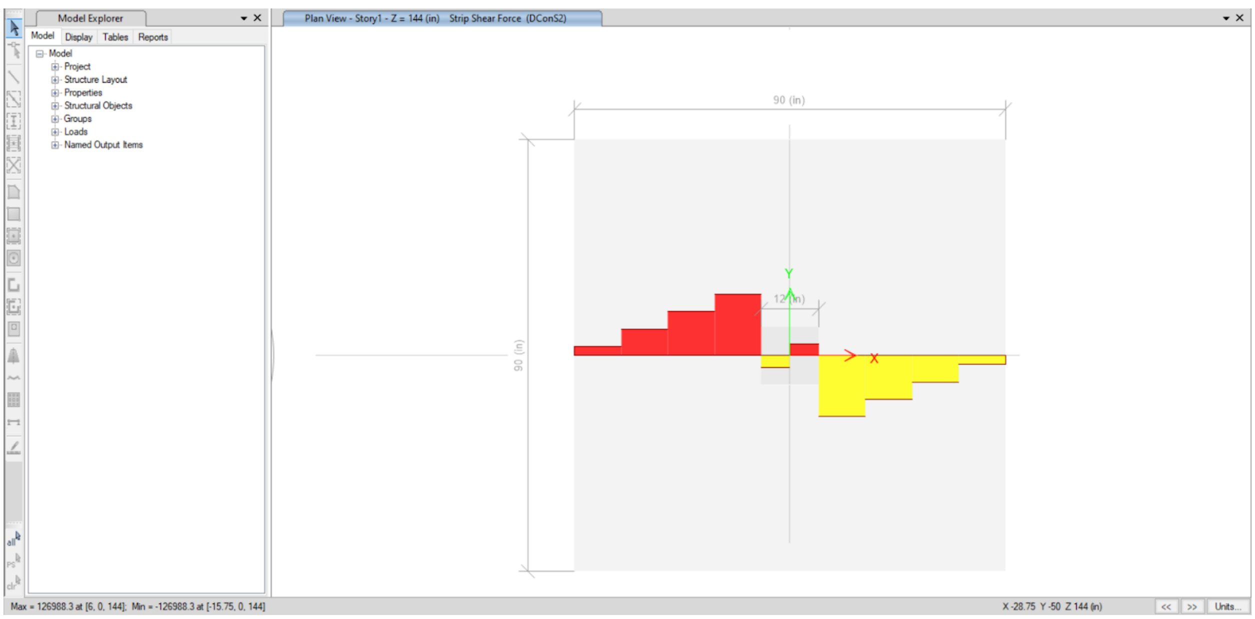


Figure 122: Footing 6 Shear Diagram

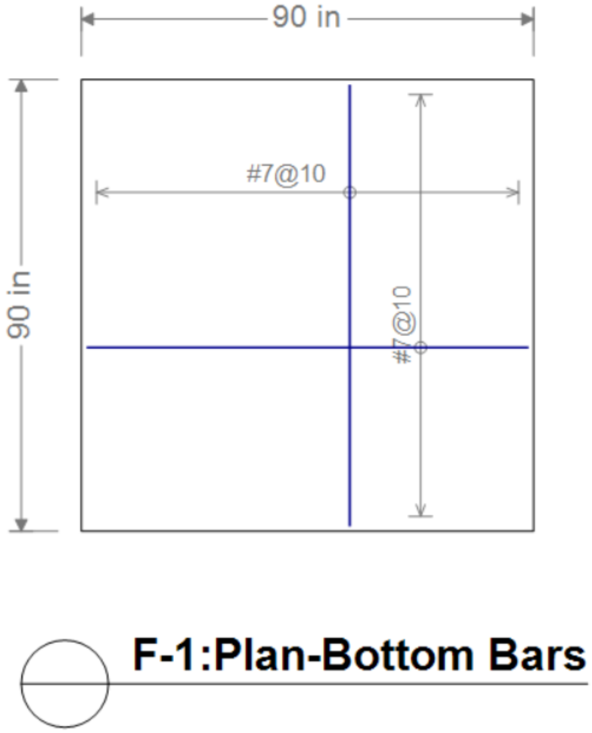


Figure 123: Footing 6 Steel Layout

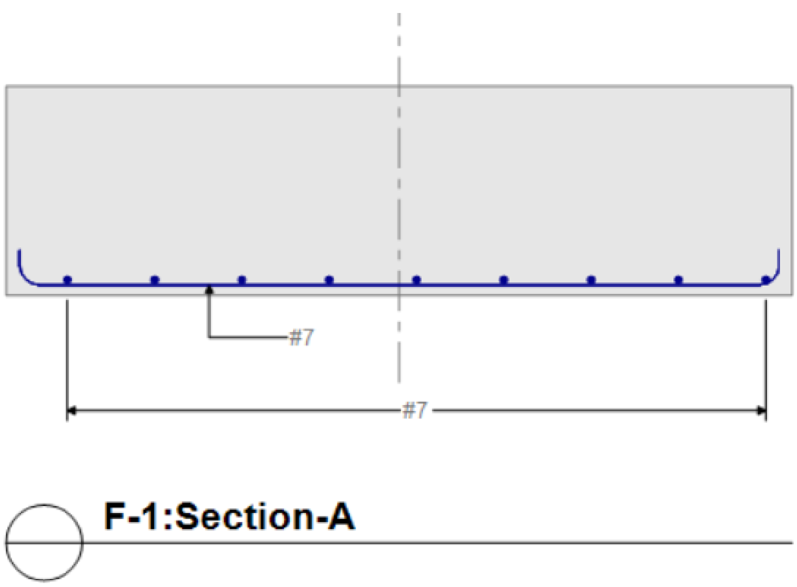


Figure 124: Footing 6 Cross Section

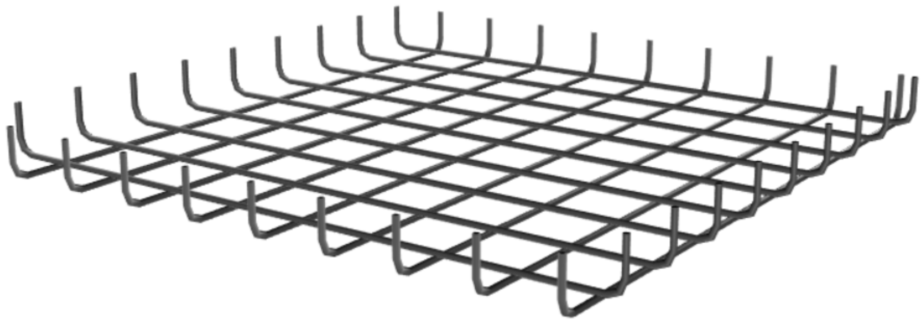


Figure 125: Footing 6; 3D Steel Layout

Footing 7

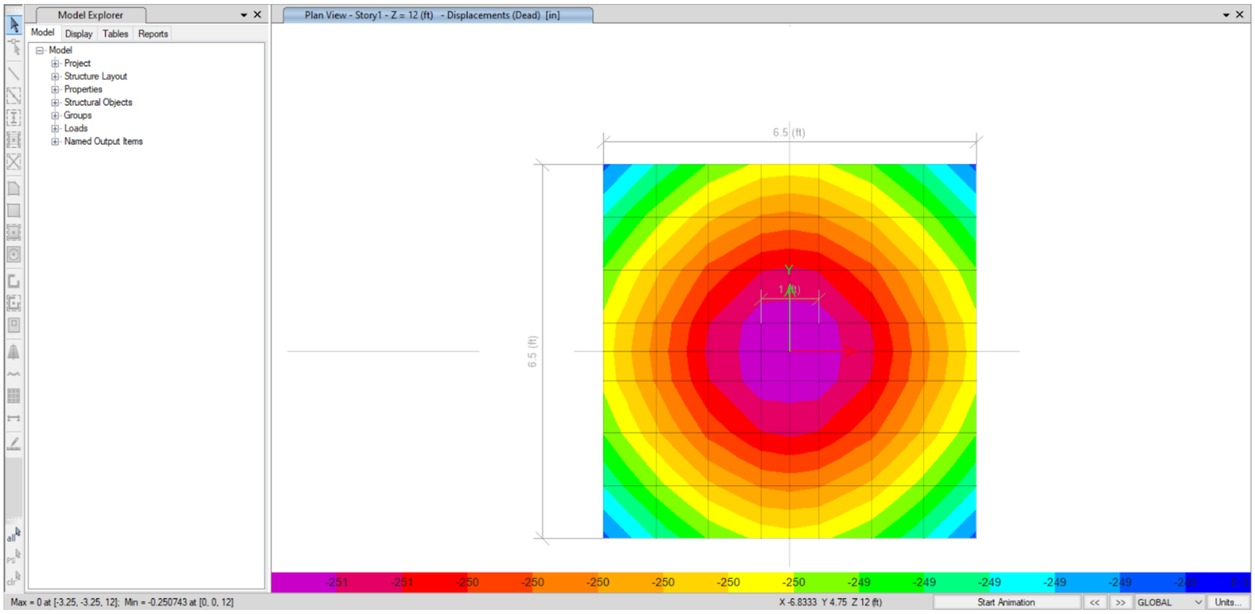


Figure 126: Footing 7 Deflection

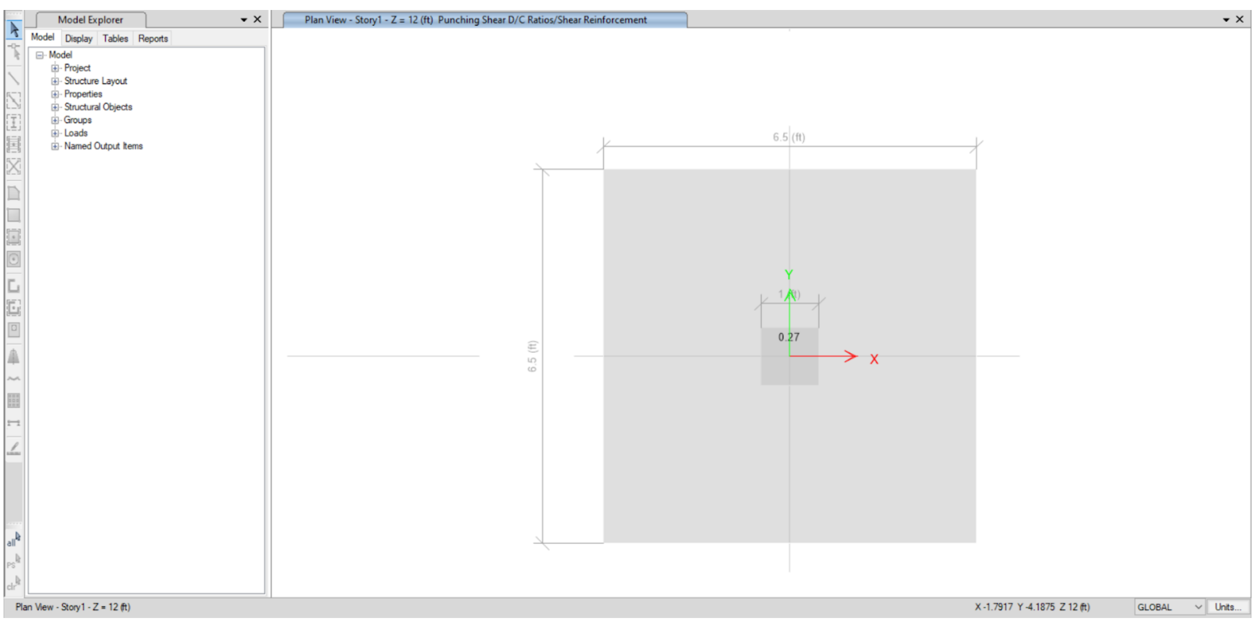


Figure 127: Footing 7 Shear Check

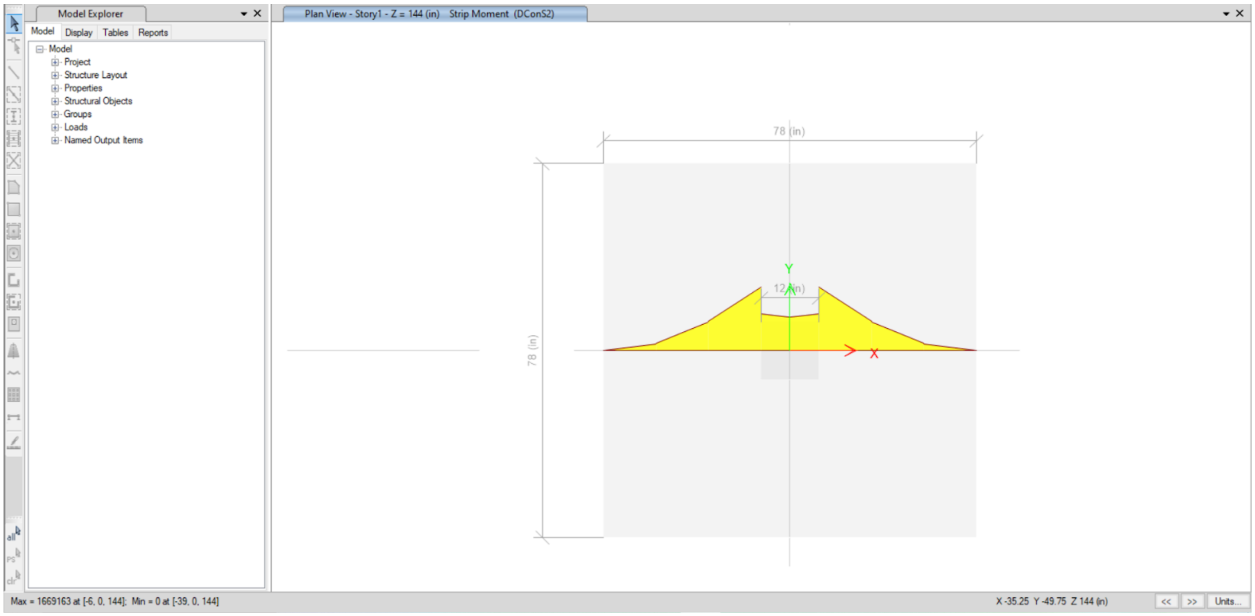


Figure 128: Footing 7 Bending Diagram

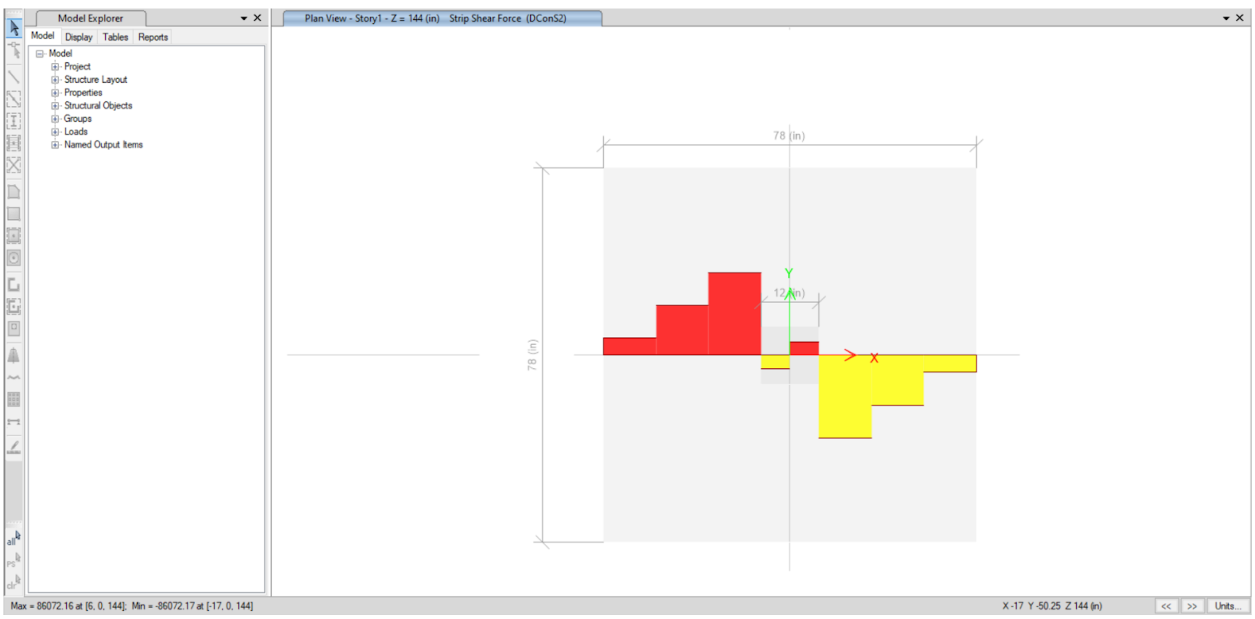


Figure 129: Footing 7 Shear Check

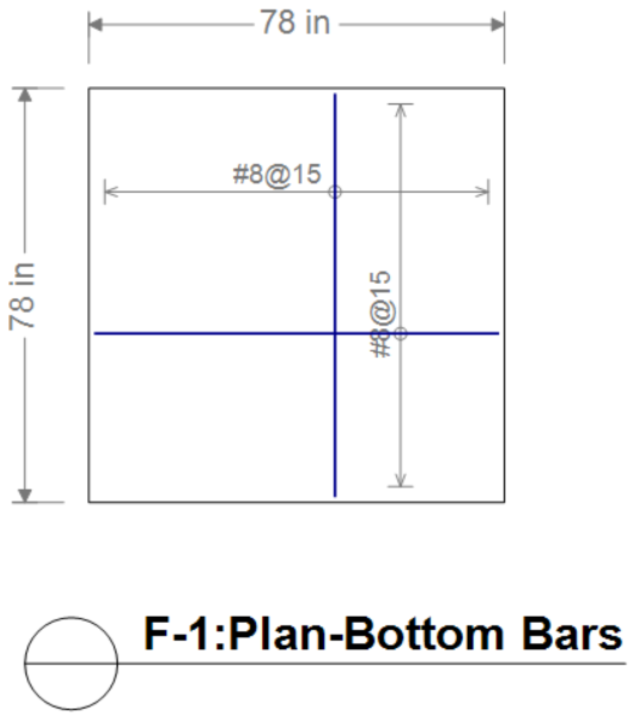


Figure 130: Footing 7 Steel Layout

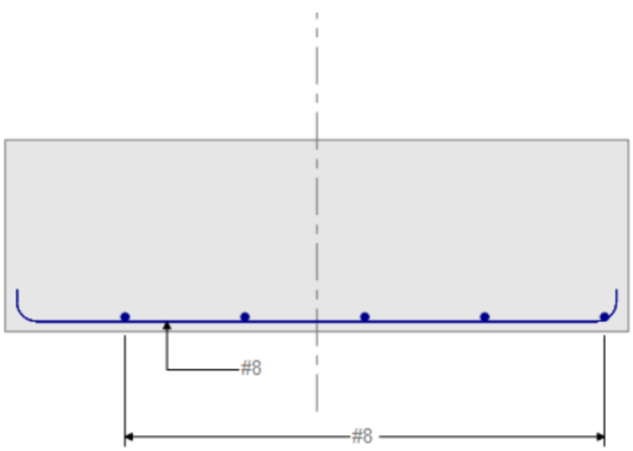


Figure 131: Footing 7 Cross Section

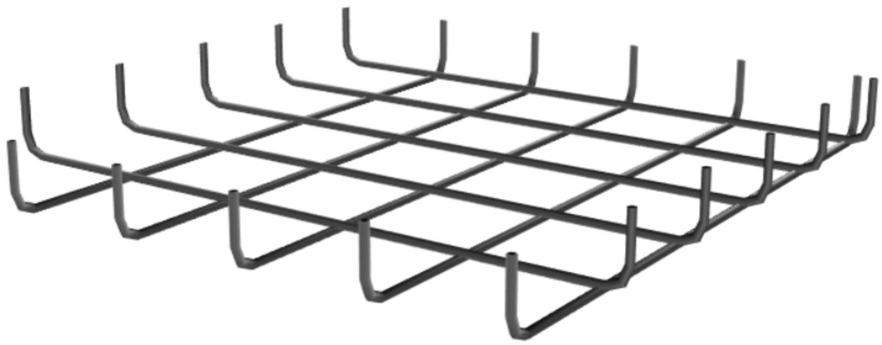


Figure 132: Footing 7; 3D Steel Layout

Footing 8

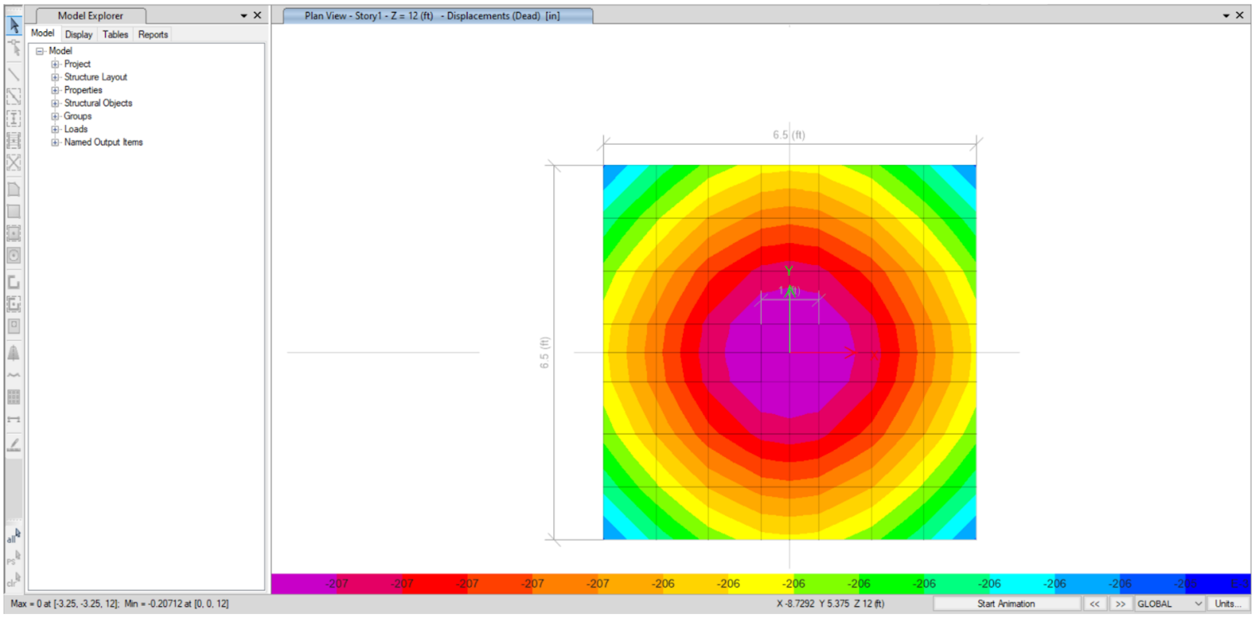


Figure 133: Footing 8 Deflection

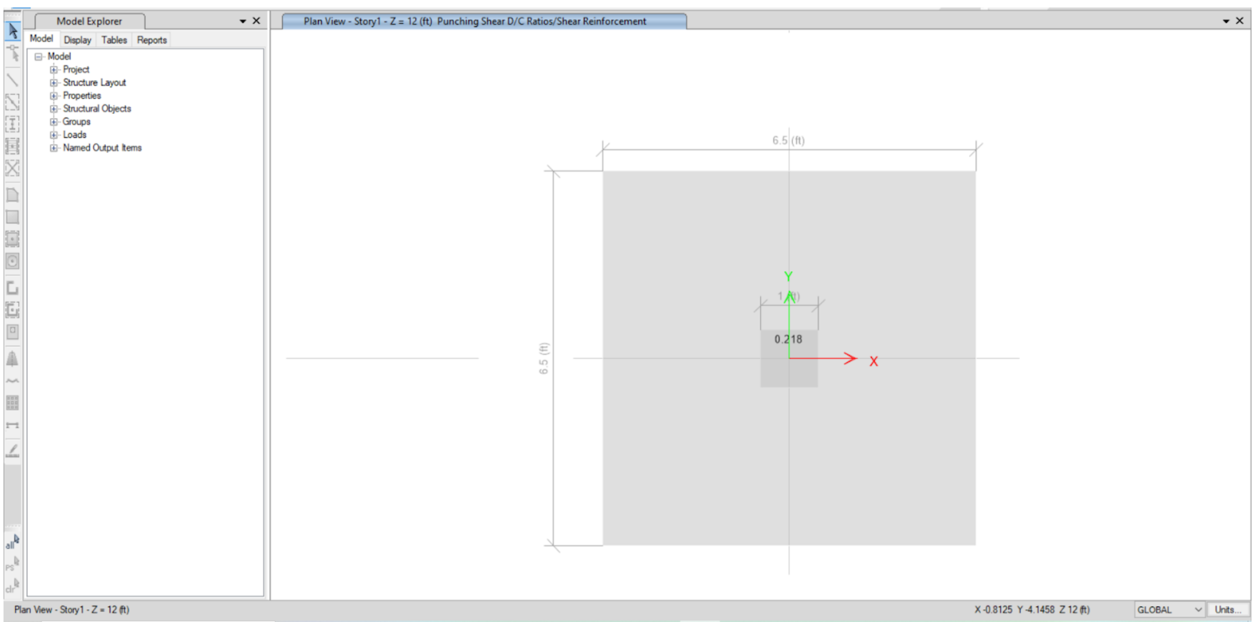


Figure 134: Footing 8 Shear Check

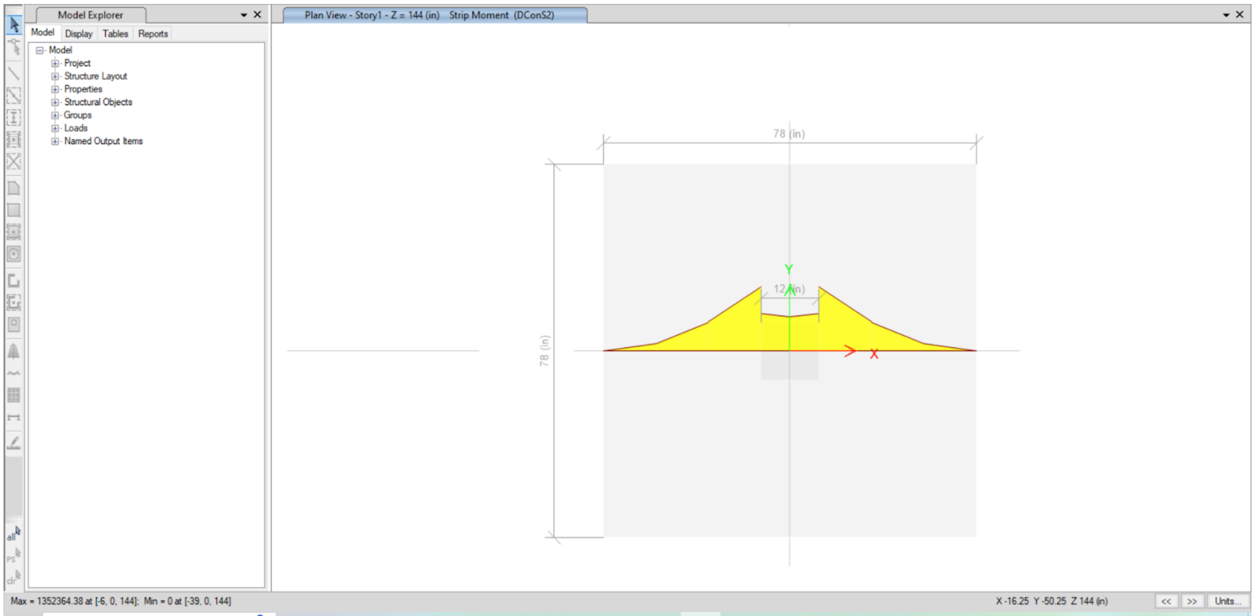


Figure 135: Footing 8 Bending Diagram

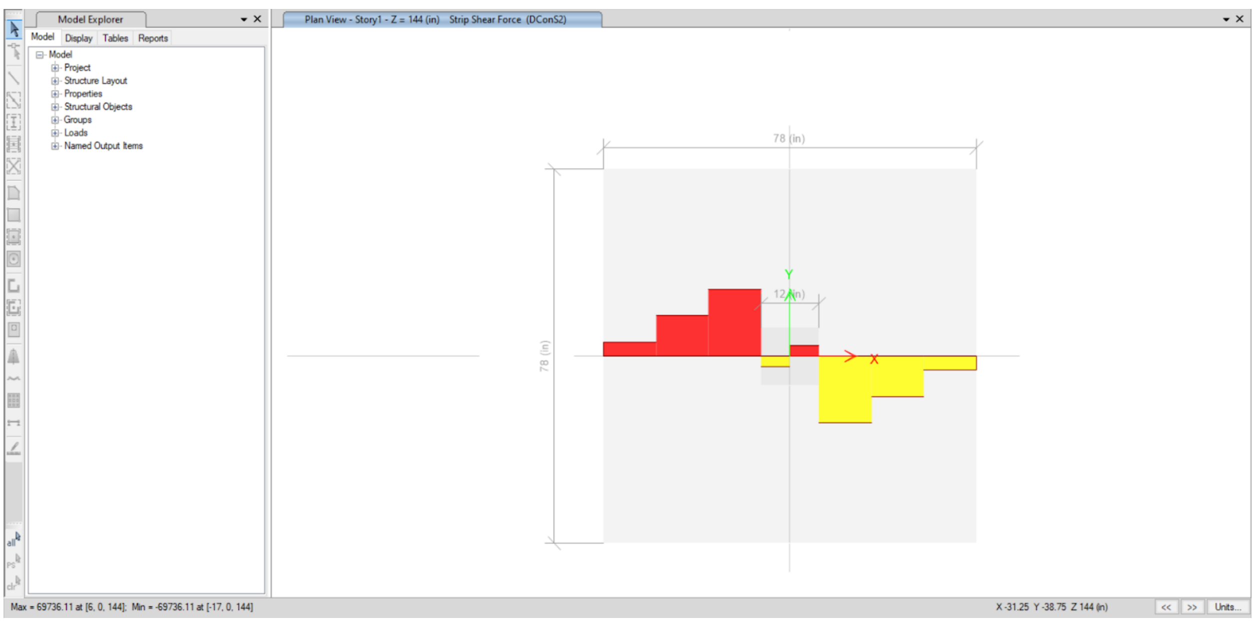


Figure 136: Footing 8 Shear Diagram

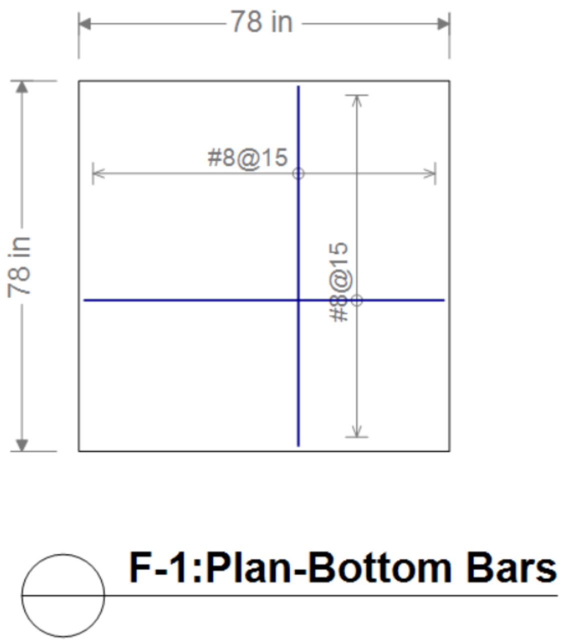


Figure 137: Footing 8 Steel Layout

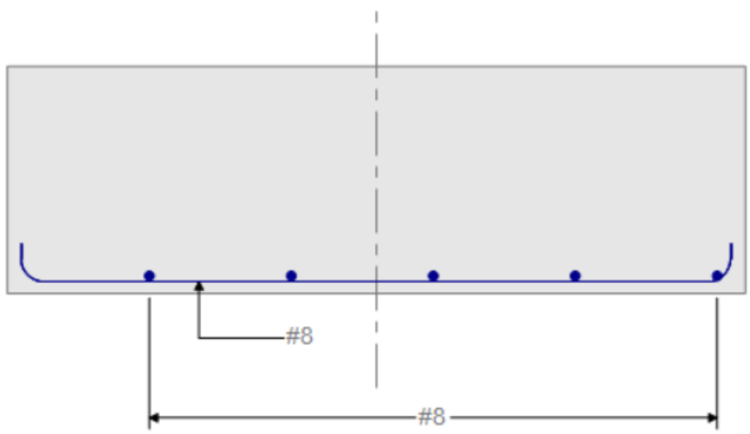


Figure 138: Footing 8 Cross Section

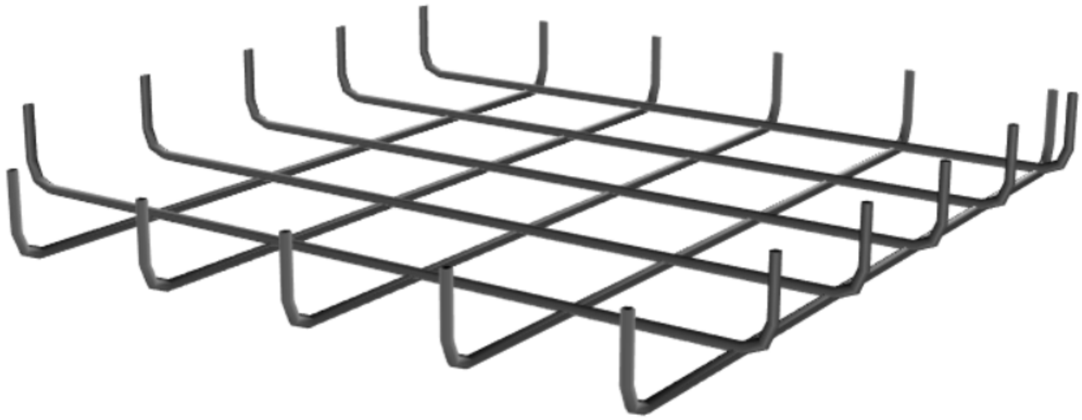


Figure 139: Footing 8 3D Steel Layout

Footing 9

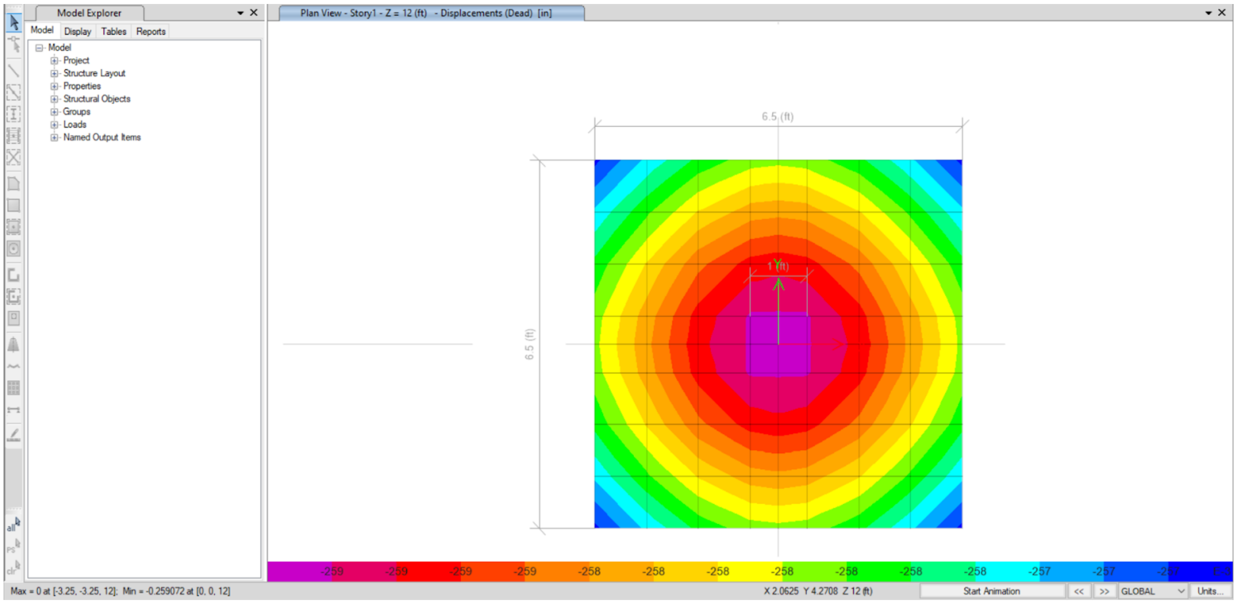


Figure 140: Footing 9 Deflection

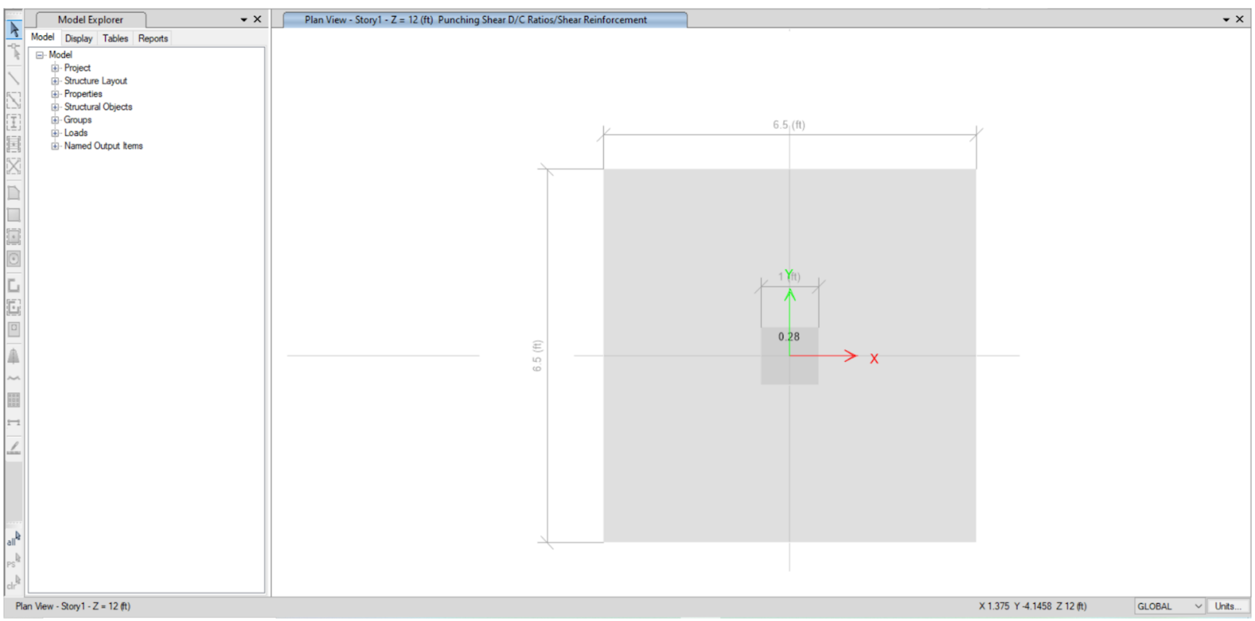


Figure 141: Footing 9 Shear Check

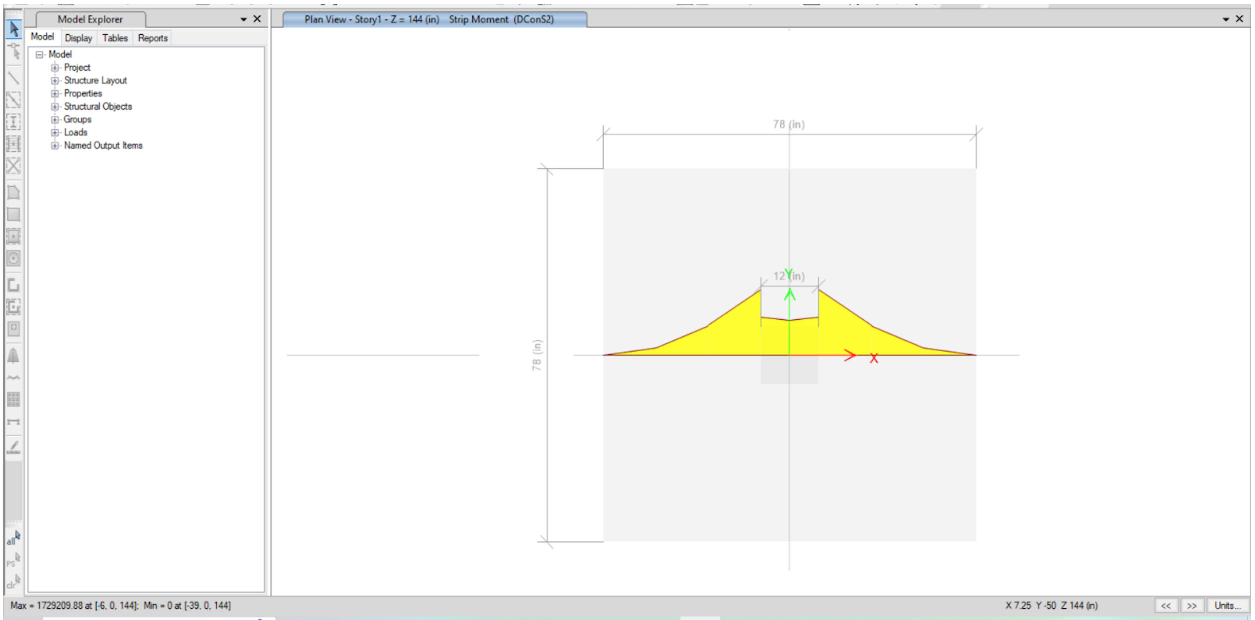


Figure 142: Footing 9 Bending Moment

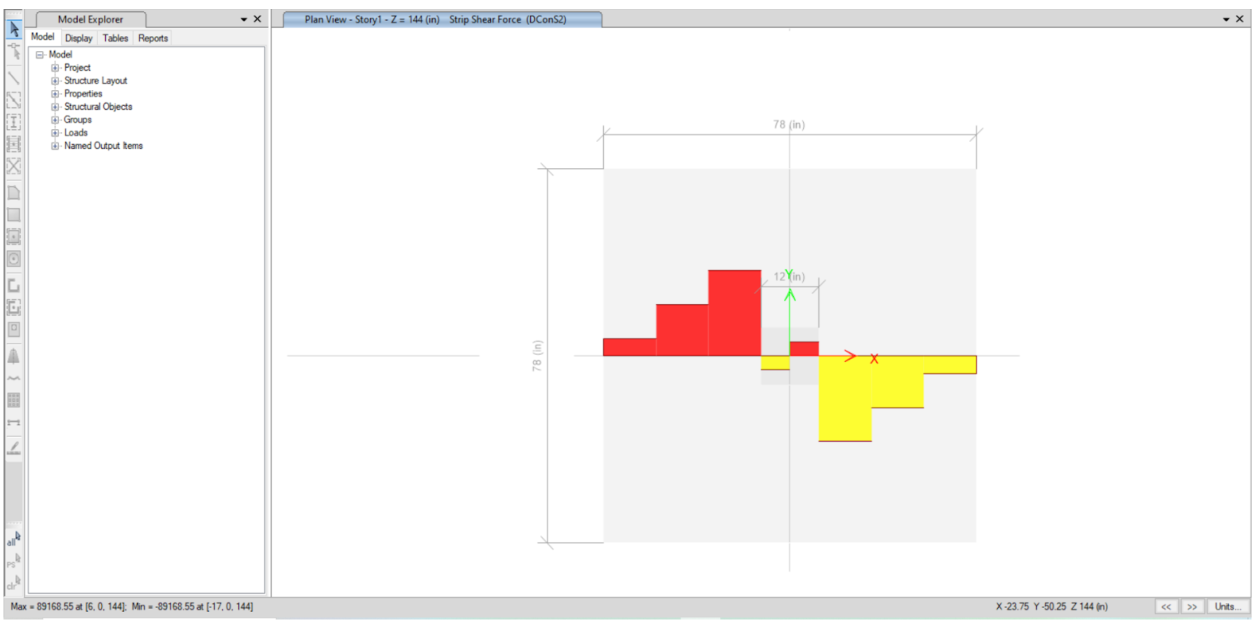


Figure 143: Footing 9 Shear Diagram

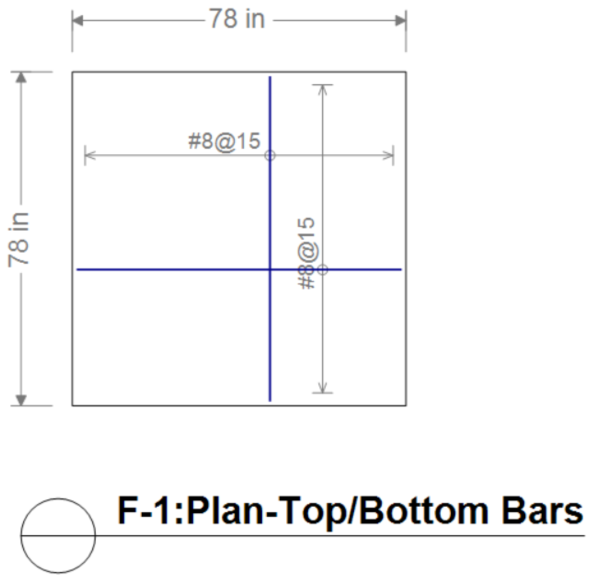


Figure 144: Footing 9 Steel Layout

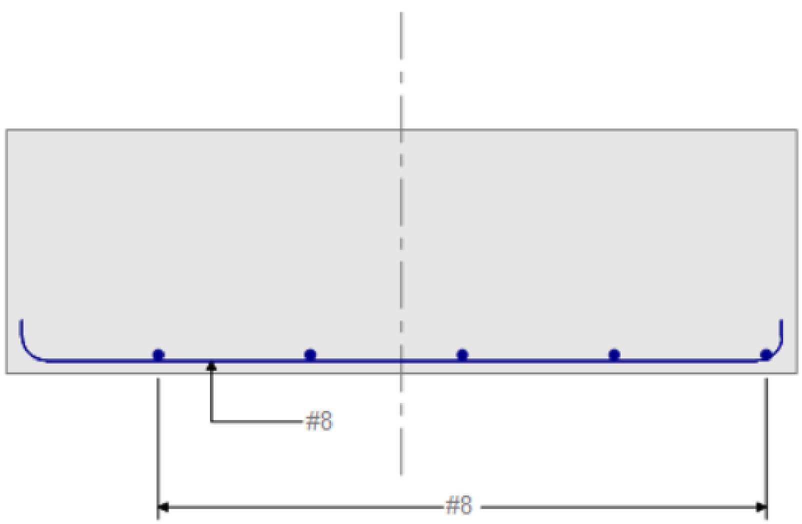


Figure 145: Footing 9 Cross Section

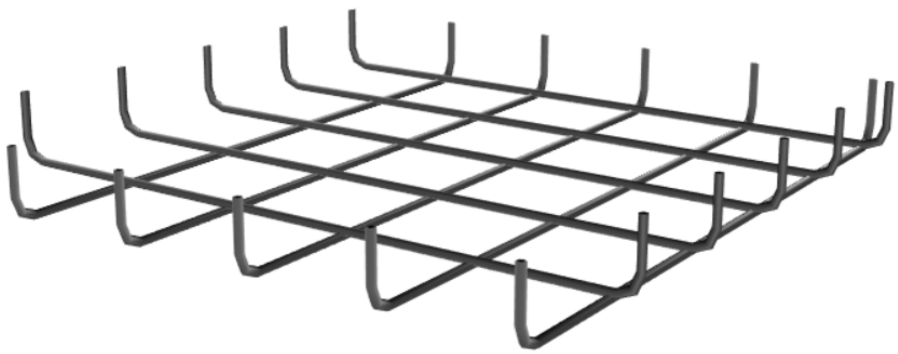


Figure 146: Footing 9; 3D Steel Layout

Slab-on-Ground

Since all of the loads we are applying to our structure are being transmitted to square footings and wall strip footings we found the need to compute a slab on grade for the first floor. Referencing code from ACI 318-19 we were unable to find any sections related to the design of reinforced concrete slabs on the ground. The code book that references it is called ACI 360R-10 "Guide to Design of Slabs-on-Ground". However, we were unable to find access to a copy of the book. Thus we began to search for equivalent slab thickness requirements.

We were able to find that the slab thickness required for a light duty warehouse to be 6". Going off of this slab thickness we began to utilize ACI code once again and design the slab in 12" sections. For slabs the ρ_{min} required for flexure was found to be .0033 for flexure and .0018 for temperature and shrinkage.

$A_s = \rho_{min} * b * d$

$A_s = .0033 * 12" * 6" = .178\ in^2$

Thus the required steel for flexure we utilized was #3 bars at 7.5" o.c. in both directions.

Settlement

The Geo-Tech team needed to calculate the settlement of the footings. They did this in two ways. One: they used the software program called SAFE. Two: they used an Excel worksheet called Schmertmann's settlement. The Geo-Tech team believes that the settlements obtained by SAFE are the more accurate ones. The Geo-tech team dismisses the settlements obtained by Schmertmann's settlement because the Geo-tech team did not fully understand how to use Schmertmann, so they believe that the results obtained using that are false. The results from using SAFE are as follows: Footing 1 is 0.16in, Footing 2 is 0.24in, Footing 3 is 0.23in, Footing 4 is 0.17in, Footing 5 is 0.21in, Footing 6 is 0.26in, Footing 7 is 0.25in, Footing 8 is 0.11in, Footing 9 is 0.26in. The results using Schmertmann are as follows: Footing 1 is 0.34in, Footing 2 is 0.91in, Footing 3 is 0.93in, Footing 4 is 0.39in, Footing 5 is 0.54in, Footing 6 is 1.23in, Footing 7 is 1.04in, Footing 8 is 0.81in, Footing 9 is 1.08in. The team then calculated the differential settlement between several footings. They did this for both SAFE and Schmertmann. The footings that were chosen were 1 to 6, 1 to 8 and 1 to 9. The formula used was:

$$DS= (S1-S2)/L$$

Using SAFE the first differential settlement, 1 to 6, was DS= (0.26-0.16)/294 = 3.4x10^-4 inches. The second differential settlement, 1 to 8, was 1.0x10^-4 inches. The third differential settlement, 1 to 9, was 1.3x10^-4 inches. Using Schmertmann the first differential settlement, 1 to 6, was 3.0x10^-3 inches. The second differential settlement, 1 to 8, was 9.6x10^-4 inches. The third differential settlement, 1 to 9, was 9.5x10^-4 inches. As stated above the Geo-Tech team believes that the SAFE settlements are the correct and most accurate ones.

SETTLEMENT ANALYSIS OF SHALLOW FOUNDATIONS
Schmertmann Method

Date	April 29, 2023				
Identification	Footing 1				
Input			**Results**		
Units	E	E or SI			
Shape	SQ	SQ, CI, CO, or RE	q =	3899	lb/ft^2
B =	3.5	ft	delta =	0.34	in
L =	3.5	ft			
D =	3	ft			
P =	42.25	k			
Dw =	25.9	ft			
gamma =	104	lb/ft^3			
t =	50	yr			

Figure 147: Schmertmann Settlement Footing 1

SETTLEMENT ANALYSIS OF SHALLOW FOUNDATIONS
Schmertmann Method

Date	April 29, 2023				
Identification	Footing 2				
Input			**Results**		
Units	E	E or SI			
Shape	SQ	SQ, CI, CO, or RE	q =	6239	lb/ft^2
B =	6	ft	delta =	0.91	in
L =	6	ft			
D =	5	ft			
P =	197.6	k			
Dw =	25.9	ft			
gamma =	104	lb/ft^3			
t =	50	yr			

Figure 148: Schmertmann Settlement Footing 2

SETTLEMENT ANALYSIS OF SHALLOW FOUNDATIONS
Schmertmann Method

Date	April 29, 2023				
Identification	Footing 3				
Input			**Results**		
Units	E	E or SI			
Shape	SQ	SQ, CI, CO, or RE	q =	5981	lb/ft^2
B =	6.5	ft	delta =	0.93	in
L =	6.5	ft			
D =	5	ft			
P =	221	k			
Dw =	25.9	ft			
gamma =	104	lb/ft^3			
t =	50	yr			

Figure 149: Schmertmann Settlement Footing 3

SETTLEMENT ANALYSIS OF SHALLOW FOUNDATIONS
Schmertmann Method

Date	April 29, 2023				
Identification	Footing 4				
Input			**Results**		
Units	E	E or SI			
Shape	SQ	SQ, CI, CO, or RE	q =	4398	lb/ft^2
B =	4	ft	delta =	0.39	in
L =	4	ft			
D =	5	ft			
P =	58.37	k			
Dw =	25.9	ft			
gamma =	104	lb/ft^3			
t =	50	yr			

Figure 150: Schmertmann Settlement Footing 4

SETTLEMENT ANALYSIS OF SHALLOW FOUNDATIONS
Schmertmann Method

Date	April 29, 2023				
Identification	Footing 5				
Input			**Results**		
Units	E	E or SI			
Shape	SQ	SQ, CI, CO, or RE	q =	5625	lb/ft^2
B =	4	ft	delta =	0.54	in
L =	4	ft			
D =	5	ft			
P =	78	k			
Dw =	25.9	ft			
gamma =	104	lb/ft^3			
t =	50	yr			

Figure 151: Schmertmann Settlement Footing 5

SETTLEMENT ANALYSIS OF SHALLOW FOUNDATIONS
Schmertmann Method

Date	April 29, 2023				
Identification	Footing 6				
Input			**Results**		
Units	E	E or SI			
Shape	SQ	SQ, CI, CO, or RE	q =	6666	lb/ft^2
B =	7.5	ft	delta =	1.23	in
L =	7.5	ft			
D =	5	ft			
P =	332.8	k			
Dw =	25.9	ft			
gamma =	104	lb/ft^3			
t =	50	yr			

Figure 152: Schmertmann Settlement Footing 6

SETTLEMENT ANALYSIS OF SHALLOW FOUNDATIONS
Schmertmann Method

Date	April 29, 2023				
Identification	Footing 7				
Input			Results		
Units	E	E or SI			
Shape	SQ	SQ, CI, CO, or RE	q =	6483	lb/ft^2
B =	6.5	ft	delta =	1.04	in
L =	6.5	ft			
D =	5	ft			
P =	242.2	k			
Dw =	25.9	ft			
gamma =	104	lb/ft^3			
t =	50	yr			

Figure 153: Schmertmann Settlement Footing 7

SETTLEMENT ANALYSIS OF SHALLOW FOUNDATIONS
Schmertmann Method

Date	April 29, 2023				
Identification	Footing 8				
Input			Results		
Units	E	E or SI			
Shape	SQ	SQ, CI, CO, or RE	q =	5396	lb/ft^2
B =	6.5	ft	delta =	0.81	in
L =	6.5	ft			
D =	5	ft			
P =	196.3	k			
Dw =	25.9	ft			
gamma =	104	lb/ft^3			
t =	50	yr			

Figure 154: Schmertmann Settlement Footing 8

SETTLEMENT ANALYSIS OF SHALLOW FOUNDATIONS
Schmertmann Method

Date	April 29, 2023				
Identification	Footing 9				
Input			**Results**		
Units	E	E or SI			
Shape	SQ	SQ, CI, CO, or RE	q =	6688	lb/ft^2
B =	6.5	ft	delta =	1.08	in
L =	6.5	ft			
D =	5	ft			
P =	250.9	k			
Dw =	25.9	ft			
gamma =	104	lb/ft^3			
t =	50	yr			

Figure 155: Schmertmann Settlement Footing 9

Cost Estimation of Materials

In order to find the costs associated with our project we went off based on the average values of materials in the City of Santa Ana. We utilized a concrete cost of $125 per cubic yard. A rebar cost of $2.00 per pound. And lastly we found the excavation cost to be $10 per cubic yard. Calculating these values we find that the total geotechnical cost for earthwork, concrete, and rebar to be $79,850.00 which includes a 10 percent increase for variation in prices.

Table 124: Square Footing Cost

Total Materials		Material Cost		Total Cost	
Total Weight of Rebar [lb]	1094.23	Cost of Rebar [$/lb]	1.25	Rebar	$ 1,367.79
Total Volume of Concrete [yd^3]	14.59	Cost of Concrete [$/yd^3]	125.00	Concrete	$ 1,823.50
				Σ	$ 3,191.28

Table 125: Strip Footing Cost

Total Materials		Material Cost		Total Cost	
Total Weight of Rebar [lb]	701.8	Cost of Rebar [$/lb]	1.25	Rebar	$ 877.29
Total Volume of Concrete [yd^3]	447.2	Cost of Concrete [$/yd^3]	125.00	Concrete	$ 55,904.30
				Σ	$ 56,781.59

Table 126: On-Grade Slab Cost

Total Materials		Material Cost		Total Cost	
Total Slab Rebar Weight [lb]	2625.88	Cost of Rebar [$/lb]	1.25	Rebar	$ 3,282.34
Total Volume [yd^3]	34.39	Cost of Concrete [$/yd^3]	125.00	Concrete	$ 4,298.61
				Σ	$ 7,580.96

Table 127: Excavation Costs for Footings

Total Material		Excavation Cost		Total Cost	
Total Footing Excavation [yd^3]	56.57	Cost of Excavation [$/yd^3]	10	Excavation	$ 5,038.08
Total Strip Wall Excavation [yd^3]	447.23			Σ	
Σ	503.81			Σ	$ 5,038.08

Table 128: Total Material and Excavation Cost for Geotechnical

Material Expense	$
Spread Footing	3191.28
Strip Footings	56781.59
Slab	7580.96
Excavation	5038.08
Σ	$ 79,851

Conclusion

Overall the design for the foundation could have had considerable improvements in design. Especially with the design of the strip footing. The strip wall footing that was designed did not consider lateral loads that would place both shear and moment on our wall. This design implementation is extremely crucial in the design of the building and is something that could be drastically improved on. Since the site is located in an active seismic region this design implementation would allow for our structure to be able to resist earthquakes especially as our building has a high mass due to the material used throughout the building being mostly concrete.

Another way we could have implemented a better design in our square footings would have been to have moments applied from the column considered. These loads would increase the requirements of the square footings. By only taking into account the column loads we did not consider any overturning moments that the square footings would in reality experience.

Another way we could have implemented a better design could have been how we distributed the loads from the slabs to beams to girders. A significant amount of load was carried by only a few of the footings. This led to very high settlement to be experienced by only a few footings. By distributing the load much better we can decrease both the loads of the footings and the size requirements.

Ethical Considerations

In the design of the building it is important to account for the ethical considerations in our design. By referencing the ASCE code of Ethics as engineers we should "create safe, resilient and sustainable infrastructure". But in doing so we must also utilize our knowledge and skills to enhance the quality of life for humanity". In this project we have tried our best to apply the engineering we have learned throughout our time here as students at CSULB to create a project to meet the needs of veterans by creating a rehabilitation center. This project proved to be a real test of our abilities especially as we had numerous design constraints to consider because of the design of the building and it required that we learn how to use new software for the first time.

Utilizing this new software required us to study on Youtube for educational videos on how to use the software really opened our eyes on how software is really used in industry. The two programs we utilized called ASDIP and Safe by CSI required us to obtain limited trial versions which put a time constraint on how long we could learn to use the software for our project but also implement the design into our project. Using these trial softwares we learned that some of the paid features were not included and had to find other ways to implement design parameters.

Due to the irregular shape of the building both the structural and geotechnical team were always in constant communication on how we could implement the best design possible. Creating an efficient design meant that all of the most of the structural elements had to be designed individually as some of the structural elements had significantly higher service loads required. If we had kept only one design for the footings we would have wasted lots of material as that column would be significantly stronger than needed.

References

1- American Concrete Institute. (2019). *ACI 318-19: Building Code Requirements for Structural Concrete: Commentary on building code requirements for structural concrete (Aci 318R-19)*.

2- American Society of Civil Engineers. (2017). *ASCE 7-16 Minimum design loads and associated criteria for buildings and other structures*.

3-Das, B. M., & Sivakugan, N. (2019). *Principles of Foundation Engineering 3rd edition*. Cengage Learning.

4-McCormac, J. C. (2015). *Design of reinforced concrete, 10th edition*. John Wiley & Sons.

5- Concrete cost per yard in Santa Ana, California. (n.d.). Retrieved April 29, 2023, from https://www.homeblue.com/concrete/santa-ana-ca-concrete-cost-per-yard.htm

6- *2023 Excavation Costs - Calculator & Prices by Project & Hour*. HomeGuide. (n.d.). Retrieved April 29, 2023, from https://homeguide.com/costs/excavation-cost

Transportation

Scope of Work

Our proposed project is located at 1801 Parkcourt Place, Santa Ana, CA 92701, West of the intersection of Cabrillo Park Drive and Parkcourt Place. This location is less than a half of a mile away from the I-5 freeway and is surrounded by residential, commercial, and recreational establishments. Cabrillo Park Drive is a minor arterial road and Parkcourt Place/Mabury Street is a major collector that spans for several residential blocks North of our site. The main entrance is located approximately 776 ft West of the intersection of Cabrillo Park Drive and Parkcourt Place. Parkcourt Place runs West to East and turns into Mabury Street, which runs North to South. We will be providing a detailed transportation evaluation and design for our proposed project including: traffic analysis, design constraints, trip generation, level of service (LOS), traffic signal warrant evaluation, Synchro analysis, collision diagrams, proposed street improvements and parking lot design, pavement design calculations, vendor catalog, and the cost estimation for our proposal.The transportation design adheres to the Municipal Codes of the City of Santa Ana and Citywide Design Guidelines, California Sign Specification (CalTrans), California Highway Design Manual, Federal Highway Administration (FHWA), California Manual on Uniform Traffic Control Devices (MUTCD), and Americans with Disabilities Act (ADA) guidelines for parking lot design. We also incorporated the use of a Natural Gas Vehicle that will provide a free shuttle service for our clients due to the limited parking availability directly in front of the proposed location. Our potential clients may have accessibility requirements that would prevent them from walking directly from their car to our facility. Our Natural Gas Vehicle will drop them off directly in front of the building and provide assistance, if needed. We designed our parking lot to accommodate on-site parking for our Natural Gas Vehicle.

Figure 156: Aerial Map of Proposed Location for Apex

Natural Gas Brief Overview

One of the future transportation engineers in our group currently works for a natural gas company. She was able to work out a van loaning agreement where we are able obtain a natural gas van free of charge and free gas, in exchange for marketing coverage of the company (i.e., the shuttle van will retain most of the original company designed logos). Her company specializes in renewable natural gas (RNG) where the transportation fuel is made from organic waste. It drastically reduces carbon emissions by an average of 300% versus diesel…unlike conventional natural gas, renewable gas is not a fossil fuel and does not involve drilling (Clean Energy Fuels, n.d.). Her company pioneered renewable natural gas as a vehicle fuel in the U.S. and continues to be the largest provider of renewable natural gas to this day. They have an extensive network of over 590 fuel stations across North America and they also have a station in Santa Ana, CA that is only 5 miles away from the site location. The employees who service the shuttle van will be able to get natural gas within an 11 minute drive from our proposed location.

Figure 157: Natural Gas Station in Santa Ana, CA

Existing Conditions

Parkcourt Place and Cabrillo Park Drive

The 1800 block of Parkcourt Place has a variety of different businesses and establishments ranging from law offices, tax preparation services and a Lutheran church. There is available parking in the neighboring businesses east of our proposed location.Our existing parking lot does not contain enough square footage to accommodate the needs of our future clients, so we have designed a near zero carbon footprint solution to make their experience stress-free. We have an agreement with the neighboring businesses where we will offer a free shuttle service for our clients and they can park in the auxiliary parking spaces and we will pick them up in our natural gas shuttle vehicle. We also have provided parking for the van in our parking lot design.

The main intersection is unsignalized where Parkcourt Place has two lanes for through traffic, one lane for Westbound traffic and one lane for Eastbound traffic. EB traffic on Parkcourt Place has a R1-1 “Stop,” sign and drivers can choose to continue through to additional business East of Cabrillo Park Drive, turn left to head North on Cabrillo Park Drive, or turn right onto SB Cabrillo Park Drive. Currently, there are no protected left or right turn lanes on Parkcourt Place and there are no turning guidelines. Cabrillo Park Drive runs North to South and has one designated left-turn lane for North & South traffic on Cabrillo Park Drive., with two additional through lanes in each direction. The speed limit on Cabrillo Park Drive is 35 MPH and Parkcourt Place/Mabury Street is 25 MPH, due to the residential area.

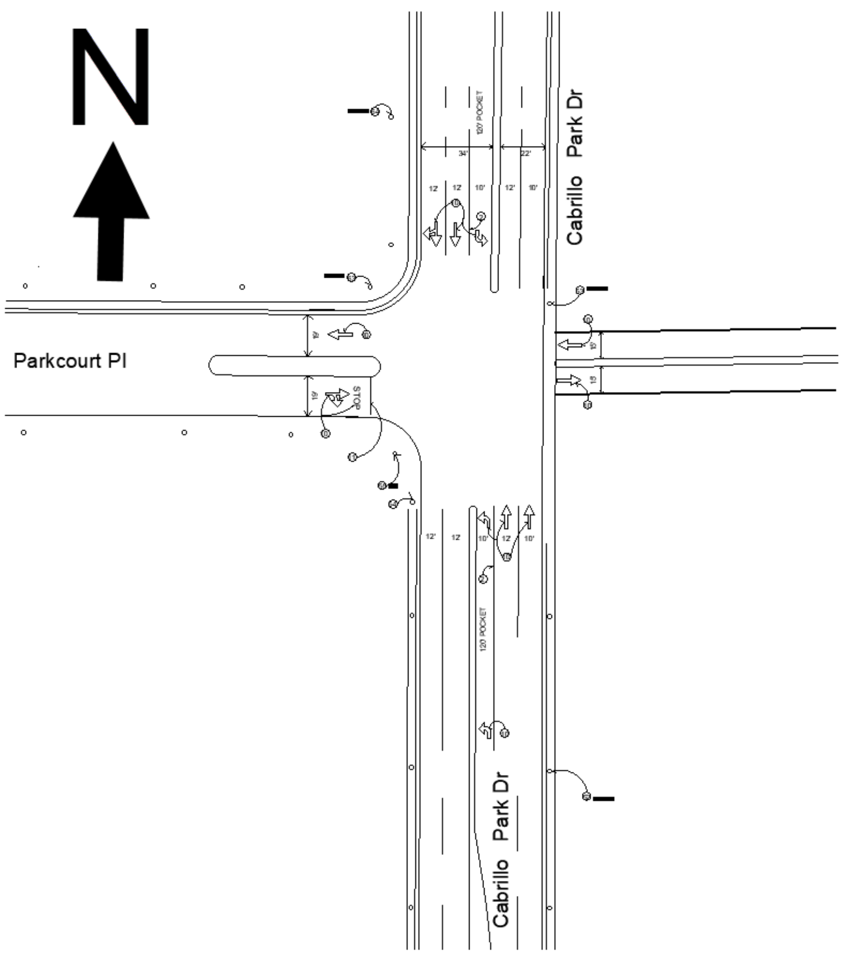


Figure 158: Existing Conditions - Cabrillo Park Drive & Parkcourt Place

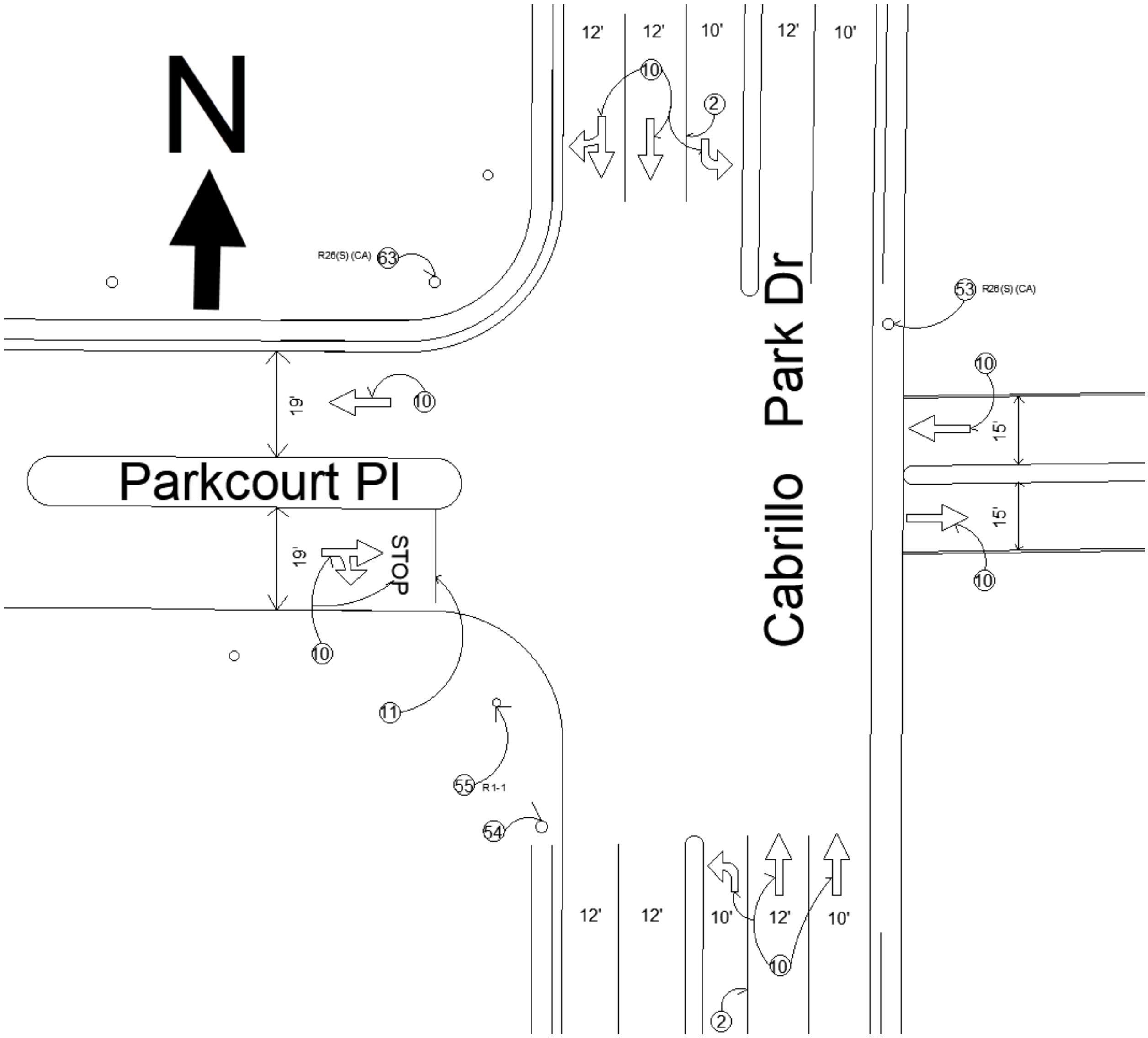


Figure 159: Close Up 1 - Existing Conditions - Cabrillo Park Drive & Parkcourt Place

Legend	Note #	Note
	2	White Turn Lane Line Per City of SA Place 1125B-1, Detail ‘2’
	10	Pavement Marking Arrows, per CA MUTCD 2014
	11	12’ Wide White Limit Line/Stop Bar, per CA MUTCD 2014
	52/53/63	No Stopping Any Time, R26(S) (CA)
	54	Cabrillo Park Dr + Parkcourt Pl, D3-1
	55	Stop, R1-1

Cabrillo Park Drive and Fruit Street

Cabrillo Park Drive & Fruit St. is an unsignalized all-way stop intersection, with a R1-1 (STOP) + R1-4 (All-Way) sign per Section 2B.04 of the MUTCD. Cabrillo Park Drive runs North and South with a speed limit of 35 MPH and Fruit St runs West at 35 MPH and East with 30 MPH. Fruit St. has one lane in each direction (WE) with street parking on the N/S of the East Leg and N on the West Leg.

Cabrillo Park Drive has a designated left turn lane for WB & EB traffic and two thru lanes in each NB & SB direction. Cabrillo Park Drive has a narrow brick center median running through the center of the lane.

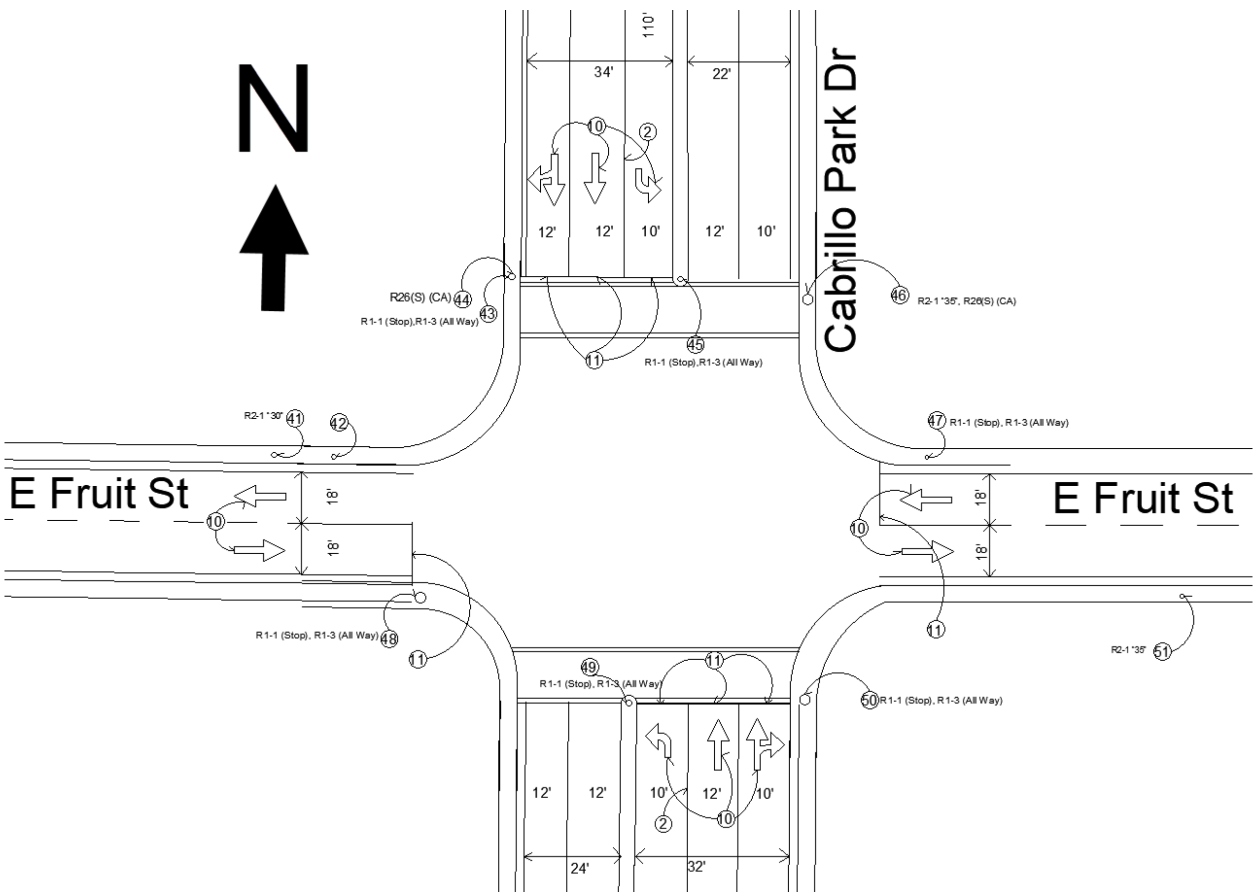


Figure 160: Existing Conditions - Cabrillo Park Drive & E Fruit Street

Legend	Note #	Note
	2	White Turn Lane Line Per City of SA Place 1125B-1, Detail ‘2’
	10	Pavement Marking Arrows, per CA MUTCD 2014
	11	12’ Wide White Limit Line/Stop Bar, per CA MUTCD 2014
	41	Speed Limit 30 MPH, R2-1 “30”
	42	No Parking This Block (Street Sweeping),
	43/45/49/50	Stop All-Way, R1-1 (Stop) + R1-2 (All Way)
	44	No Stopping Any Time, R26(S) (CA)
	46	Speed Limit 35 + No Stopping Any Time, R2-1 + R26(S) (CA)
	47/48	Stop All Way + (Fruit St + Cabrillo Park), D3-1, R1-1 + R1-3
	51	Speed Limit 35 MPH, R2-1 “35”

Cabrillo Park Drive and 4th Street

The signalized intersection of Cabrillo Park Dr and 4th St has a speed limit of 35 MPH on Cabrillo Park Dr and 4th St has a 40 MPH speed limit. On Cabrillo Park Dr’s South Leg, there are three lanes in the NB direction: a protected left turn, a left turn & through, and a through and right turn lane and the SB lanes are two through lanes On the North Leg of Cabrillo Park Drive, SB traffic has one protected left turn lane and two through lanes and NB traffic has two through lanes. On the West leg of E 4th St, EB traffic has five lanes, one designated left turn, one designated right turn, and three through lanes. WB traffic has three through lanes. On the East leg, WB traffic has one designated left turn lane and three through lanes, while EB traffic has three through lanes.

Northbound Cabrillo Park Drive. NB Cabrillo Park Drive has a protected left turn where the the first lane from the center median is left turn only with it’s signal included in the traffic controller and denoted by sign (please note, U-turns are NOT allowed), the lane to the right is a permissive left turn and through lane, and the outer lane is a through and permissive right turn. Per the MUTCD Figure 2B-4 & 2B-4 (CA) there is a specialized sign that combines R3-8 or R61-1 (CA) with the right side of R61-5 (CA). Signal Indications for Protect/Permissive Mode Left-Turn Movements via Section 4D.20 from MUTCD.

Southbound Cabrillo Park Drive. SB Cabrillo Park Drive has a protected left turn signal. There is no crosswalk for SB pedestrians and crossing is prohibited with R9-3 + R9-3bP (for N+S) approach. The pedestrian's use R10-4bR on each approach (this specific sign was not in the MUTCD 2014 Edition) and may need to be updated to R10-3 to meet requirements.

Eastbound 4th Street. EB 4th St has a protected left turn lane/signal with a R73-2 (CA) that protects the left turn and U-turns. There is a designated right turn lane only lane with a "Right Lane Must Turn Right," modified for right R3-7 sign + "No Stopping Any Time," R26(S)(CA).

Westbound 4th Street. WB 4th St has a protected left turn lane and allows U-turns with R73-2 (CA) and three through lanes. The signal mastarm follows the standard plans and mounting details for mounted U-turn signs in the MUTCD; R73-2 (CA). At the end of the mastarm, there is a "Do Not Block Intersection," sign R10-7.

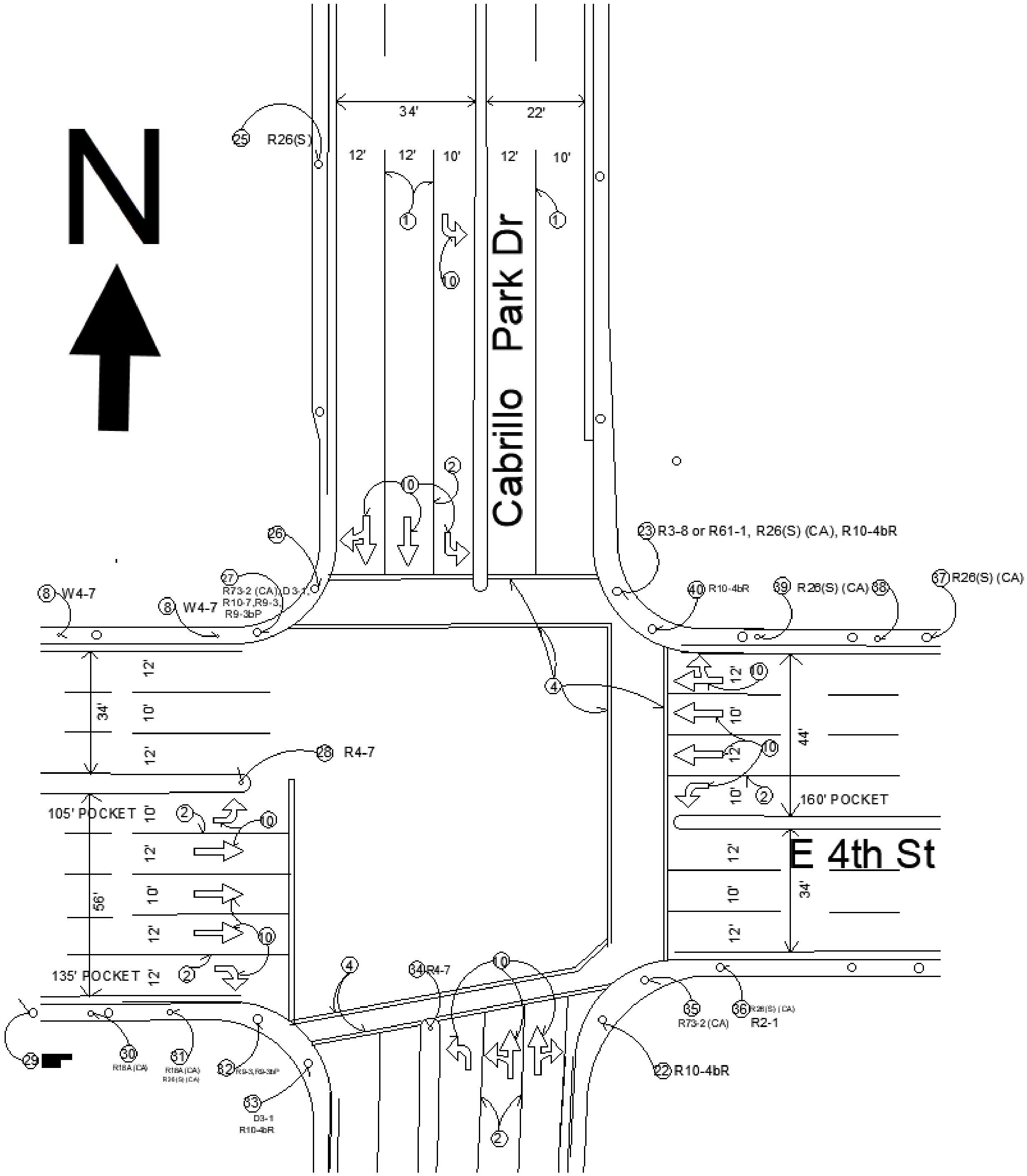


Figure 161: Existing Conditions - Cabrillo Park Drive & E 4th Street

Legend	Note #	Note
	1	White Lane Line Per City of SA Place 1125B-1, Detail '1'
	2	White Turn Lane Line Per City of SA Place 1125B-1, Detail '2'
	4	Crosswalk White Line 12' Wide @ 11' O.C.
	8	Thru Traffic Merge Left, W4-7
	10	Pavement Marking Arrows, per CA MUTCD 2014
	11	12' Wide White Limit Line/Stop Bar, per CA MUTCD 2014
	20	R3-8 or R61-1 (CA) w/ right of R61-5 (CA) + No Stopping Any Time, R26(S) (CA)
	21	To I5 North ←, E6-2a
	22	Vertical Signal + Digital Ped + Ped Button, R10-4bR
	23	Mastarm B - Typical Arrangements (See Photos Below) +R3-8 or R61-1 (CA) w/ right of R61-5 (CA) + Vertical Signal on Mastarm + 4th St, D3-1 + Mastarm Pole: Vertical Signal + Digital Ped + No Stopping Any Time, R26(S) (CA) + Ped Button, R10-4bR
	24	Speed Limit 35 + No Stopping Any Time, R2-1 "35"+ R26(S) (CA)
	25/37/39	No Stopping Any Time, R26(S) (CA)
	26	Double Sided Vertical Signal
	27	Mastarm B: Vertical Signal + R73-2 (CA) + Vertical Signal + Cabrillo Park Dr, D3-1 + Mastarm Pole: Do Not Block Intersection, R10-7 + Vertical Signal + Digital Ped + No Ped Crossing, R9-3 + Use Crosswalk →, R9-3bP
	28/34	Keep Right, R4-7
	29	Right Lane Turns Right Ahead, W73A (CA) + No Stopping Any Time, R26(S) (CA)
	30	Right Lane Must Exit, R18A (CA)
	31	R18A (CA) + No Stopping Any Time, R26(S) (CA)
	32	Double Sided Vertical Signal + Digital Ped + No Ped Crossing, R9-3 + Use Crosswalk →, R9-3bP

	33	Mastarm B: Vertical Signal + Left and U Turn Arrow, R73-2 (CA) + Vertical Signal on Mastarm + 4th St, D3-1 + Mastarm Pole: Vertical Signal + Ped Button, R10-4bR
	35	Mastarm: Vertical Signal + Left and U Turn Arrow, R73-2 (CA) + Cabrillo Park Dr, D3-1 Mastarm Pole: Do Not Block Intersection, R10-7 + Vertical Signal + Digital Ped + Ped Button, R10-4bR
	36	Speed Limit 40 + No Stopping Any Time, R2-1 “40”+ R26(S) (CA) + OC Bus Sign
	38	OC Bus Sign
	40	Double Sided Vertical Signal + Digital Ped + Ped Button, R10-4bR

Traffic Analysis

Traffic Counts

All of our traffic data was provided by the City of Santa Ana. We received as-builts, collision data, and 24-hour traffic counts.

Trip Generation

The Institute of Transportation Engineers (ITE) publishes a yearly edition of the ITE Trip Generation Manual. This manual presents a summary of the trip generation data that have been voluntarily collected and submitted to ITE. Trip generation helps to predict the number of trips, by purpose, that are generated by and attracted to each zone in a study area. The trip generation database includes both vehicle and person trip generation for urban, suburban and rural settings (Institute of Transportation Engineers, n.d.). Trip generation rates provide travel demand analysis for new development across the United States. Using the ITE Trip Generation Manual 11th Edition Volume 4, section Land Use: 495 Recreational Community Center (Institute of Transportation Engineers, 2021, 282-287) we were able to calculate the average rates, the directional distributions, and the trips generated by each time period.

Average Rates for Each Time Period. The table below is given in the ITE Trip Generation Manual 11th Edition Volume 4, section Land Use: 495 Recreational Community Center.

Table 129: Average Trip Rates for Each Time Period

Time Period	**Average Rate (Veh/1000 ft² GFA)**
Weekday	28.82
Weekday Peak Hour (Adjacent St) One Hour Between 7 and 9 AM	1.91
Weekday Peak Hour (Adjacent St) One Hour Between 4 and 6 PM	2.50
Weekday, AM Peak Hour	1.85
Weekday, PM Peak Hour	2.53

Directional Distributions for Each Time Period. The table below is given in the ITE Trip Generation Manual 11th Edition Volume 4, section Land Use: 495 Recreational Community Center.

Table 130: Directional Distributions of Trips for Each Time Period

Time Period	**Distribution of Trips Entering**	**Distribution of Trips Exiting**
Weekday	50%	50%
Weekday Peak Hour (Adjacent St) One Hour Between 7 and 9 AM	66%	34%
Weekday Peak Hour (Adjacent St) One Hour Between 4 and 6 PM	47%	53%
Weekday, AM Peak Hour	63%	37%
Weekday, PM Peak Hour	47%	53%

Table 131: Trips Generated By Time Period

Time Period	Trips Generated (Vehicles)		
	Entering	Exiting	Total
Weekday	51.88	51.88	103.75
Weekday Peak Hour (Adjacent St) One Hour Between 7 and 9 AM	4.54	2.34	6.88
Weekday Peak Hour (Adjacent St) One Hour Between 4 and 6 PM	4.23	4.77	9.00
Weekday, AM Peak Hour	4.20	2.46	6.66
Weekday, PM Peak Hour	4.28	4.83	9.11

The square footage of business = 3600 ft^2.

To find the Trips Generated, the following equation will be used:

$$Rate\left(\frac{Vehicles}{1000\ ft^2}\right)\times\frac{Gross\ Floor\ Area\ ft^2}{1000\ ft^2} = Trips\ Generated\ (vehicles)$$

For example, Weekday Total:

$$Rate\left(28.82\frac{Vehicles}{1000\ ft^2}\right)\times\frac{3600\ ft^2}{1000\ ft^2} = 103.75\ \ Trips\ Generated\ (vehicles)$$

To calculate the trips directional trips generated:

$$Trips\ Generated\ (vehicles)\ \times\frac{Directional\ Distribution\ \%}{100} = Directional\ Trips\ Generated\ (vehicles)$$

For example, Weekday Entering:

$$103.75\ Trips\ Generated\ (vehicles)\ \times\ 50\% = 51.88\ Directional\ Trips\ Generated\ (vehicles)$$

For example, Weekday Exiting:

$$103.75\ Trips\ Generated\ (vehicles)\ \times\ 50\% =\ 51.88\ Directional\ Trips\ Generated\ (vehicles)$$

Total Trips Generated by Time Period:

$$51.88\ DTG\ (vehicles)\ +\ 51.88\ DTG\ (vehicles)\ =103.75\ Trips\ Generated\ (vehicles)$$

MUTCD Traffic Signal Warrant Analysis

As transportation engineers we become very familiar with the Manual for Traffic Controller Devices (MUTCD). California has their own MUTCD that contains guidelines and design constraints for signs, signals, striping, placement and many other traffic related objects. Under Chapter 4C of the MUTCD 2014 (State of California et al., 2021), there are 9 Traffic Signal Warrants that determine whether installing a traffic signal is justified for a proposed project. Because our location has very low traffic volume, we also analyzed the existing signalized intersection of Cabrillo Park Drive and 4th Street to show whether the existing traffic signal is warranted. The following warrants are shown below:

1. **Eight-Hour Vehicular Volume:** there are two conditions that have to be met for this warrant to be satisfied:
    a. **Condition A:** The Minimum Vehicular Volume - intended for application at locations where a large volume of intersection traffic is the principal reason to consider installing a traffic control signal.
    b. **Condition B:** The Interruption of Continuous Traffic - intended for application at locations where Condition A is not satisfied and where the traffic volume on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or conflict in entering/crossing the major street.

2. **Four-Hour Vehicular Volume:** when the volume of intersecting traffic is the principal reason to consider installing a traffic signal.
3. **Peak Hour:** if a minimum of 1 hour on an average, the minor-street suffers delay when entering/crossing the major street, a traffic signal may be warranted. An approach's peak hour is the four, consecutive 15-minute intervals where the traffic volumes are the heaviest.
4. **Pedestrian Volume:** if the pedestrian volume is so heavy on a major street, it may warrant installing a traffic signal to alleviate excessive delay.
5. **School Crossing:** when there are schoolchildren (elementary through high school) there is a need for a traffic signal if they have to cross the major street.
6. **Coordinated Signal System**: a coordinated signal system permits continuous movement throughout a network of streets with minimum stops and delay for driving a group of vehicles together (platooning).
7. **Crash Experience:** if there is a higher frequency for crash related occurrences at an intersection (specifically 5 or more crashes in a year), this warrant can justify the need to install a traffic signal.
8. **Roadway Network:** when there is a need for organization of traffic flow due to a concentration of road users on a set of intersecting roads, this warrant can help to justify installing a traffic signal.
9. **Intersection Near a Grade Crossing:** this warrant is only intended to be used when none of the other warrants are met and involves an intersection that is in close proximity to a grade crossing with an intersection approach controlled by a STOP or YIELD sign. This was not warranted at any of the analyzed intersections.

Intersection: Cabrillo Park Drive and Parkcourt Place

Warrant Summary

STUDY AND ANALYSIS INFORMATION

Municipality:	Santa Ana	Traffic Volumes Obtained By:	City of Santa Ana
County:	Orange	Analysis Date:	3/28/2023
Caltrans Engineering District:	District 12	Agency/ Company Name Performing Warrant Analysis:	Hayden Robbins

Analysis Information

Data Collection Date:	6/11/2020
Day of the Week:	Monday
Is the intersection in a built-up area of an isolated community of <10,000 population?	No
Existing Traffic Signal at intersection:	No
Total Number of Approaches at Intersection:	4

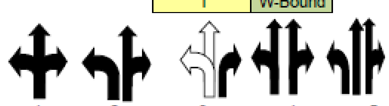
Major Street Information

Major Street Name and Route Number:	Cabrillo Park Dr
Major Street Approach Direction:	N-Bound S-Bound
Number of Thru Lanes on Each Major Street Approach:	2 LANE(S)
Speed Limit or 85th Percentile Speed on the Major Street*:	35 MPH

*Unknown assumes below 45 mph

Minor Street Information

Minor Street Name and Route Number:	Parkcourt Pl	
Minor Street Approach Configuration:	1	E-Bound
	1	W-Bound



1 2 3 4 5

Number of Thru Lanes on Each Minor Street Approach: 1 LANE(S)

TRAFFIC SIGNAL WARRANT ANALYSIS FINDINGS

	Applicable?	Warrant Satisfied?	Notes and Comments:	
Warrant 1, Eight-Hour Vehicular Volume	No			
Warrant 2, Four-Hour Vehicular Volume	No			
Warrant 3, Peak Hour	Yes	Yes	Signals installed under Warrant 3 should be traffic actuated.	Peak Hour 4:45 PM 5:45 PM
Warrant 4, Pedestrian Volume	No		If this warrant is met, and a traffic control signal is justified by an engineering study, the traffic control signal shall be equipped with pedestrian signal heads complying with the provisions set forth in Chapter 4E of the CAMUTCD.	Peak Hour 4:45 PM 5:45 PM
Warrant 5, School Crossing	No		N/A	
Warrant 6, Coordinated Signal System	No		(Shall not be used as the sole warrant in the analysis)	
Warrant 7, Crash Experience	No		If this is the sole warrant, signal must be semi-actuated with control devices which provide proper coordination if installed at an intersection within a coordinated system and normally should be fully traffic actuated if installed at an isolated intersection.	
Warrant 8, Roadway Network	No		(Shall not be used as the sole warrant in the analysis)	
Warrant 9, Intersection Near a Grade Crossing	N/A	No	Figure 4C-9	
Multi-Way Stop Warrant	No		May be used as an interim measure if traffic signal warrants are satisfied.	

The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.

Conclusion: Do Not Install New Traffic Signal

Notes:

Figure 162: Warrant Summary for Cabrillo Park Drive & Parkcourt Place

Warrant 1: Eight-Hour Vehicular Volume.

CAMUTCD WARRANT 1, EIGHT-HOUR VEHICULAR VOLUME

Number of Lanes for Moving Traffic on Each Approach	
Major Street:	2 or More Lanes
Minor Street:	1 Lane

Built up Isolated Community with Less Than 10,000 Population or Above 40 MPH on Major Street? No

*Only applicable after an adequate trial of other alternatives (See section 4C.02.06 of the 2014 CAMUTCD)

Lanes Major/ Minor	Adjusted Volumes		Condition A				Condition B				Combination A/B*							
											Cond. A		Cond. B		Cond. A		Cond. B	
	Major	Minor	100%		70%		100%		70%		80%		80%		56%		56%	
			Maj.	Min.	Maj.	Min.	Maj.	Min.	Maj.	Min.	Maj.	Min.	Maj.	Min.	Maj.	Min.	Maj.	Min.
1 / 1			500	150	350	105	750	75	525	53	400	120	600	60	280	84	420	42
2+ / 1	X		600	150	420	105	900	75	630	53	480	120	720	60	336	84	504	42
2+ / 2+			600	200	420	140	900	100	630	70	480	160	720	80	336	112	504	56
1 / 2+			500	200	350	140	750	100	525	70	400	160	600	80	280	112	420	56
12:00 AM	50	14																
12:15 AM	40	13																
12:30 AM	41	11																
12:45 AM	41	7																
1:00 AM	34	4																
1:15 AM	36	2																
1:30 AM	30	2																
1:45 AM	28	4																
2:00 AM	34	4																
2:15 AM	37	4																
2:30 AM	35	3																
2:45 AM	36	2																
3:00 AM	33	3																
3:15 AM	32	5																
3:30 AM	38	6																
3:45 AM	53	6																
4:00 AM	71	10																
4:15 AM	87	12																
4:30 AM	108	12																
4:45 AM	122	15																
5:00 AM	150	13																
5:15 AM	173	14																
5:30 AM	193	20																
5:45 AM	218	24																
6:00 AM	252	28																
6:15 AM	302	30																
6:30 AM	386	29													1			
6:45 AM	524	26			1						1						1	
7:00 AM	659	27	1						1									
7:15 AM	764	30											1					
7:30 AM	843	31													1			
7:45 AM	829	37			1						1						1	
8:00 AM	766	33	1						1									
8:15 AM	731	27											1					
8:30 AM	640	28													1			
8:45 AM	599	20			1						1						1	

Figure 163: Warrant 1 for Cabrillo Park Drive & Parkcourt Place

9:00 AM	560	18																
9:15 AM	529	22																
9:30 AM	553	25													1			
9:45 AM	540	32			1						1						1	
10:00 AM	558	37																
10:15 AM	552	31																
10:30 AM	558	32													1			
10:45 AM	587	30			1						1						1	
11:00 AM	586	37																
11:15 AM	628	43	1															
11:30 AM	633	42							1						1			
11:45 AM	649	42			1						1						1	1
12:00 PM	700	39																
12:15 PM	694	42	1															
12:30 PM	703	43							1						1			
12:45 PM	677	39			1						1						1	
1:00 PM	675	35																
1:15 PM	662	32	1															
1:30 PM	658	30							1						1			
1:45 PM	671	30			1						1						1	
2:00 PM	638	34																
2:15 PM	679	41	1															
2:30 PM	688	52							1						1			
2:45 PM	730	56			1						1		1				1	1
3:00 PM	787	50																
3:15 PM	784	51	1															
3:30 PM	795	52							1						1			
3:45 PM	796	56			1						1		1				1	1
4:00 PM	789	64																
4:15 PM	847	62	1															
4:30 PM	877	64							1	1					1			
4:45 PM	891	63			1						1		1	1			1	1
5:00 PM	886	62																
5:15 PM	828	66	1															
5:30 PM	780	62							1	1					1			
5:45 PM	733	59			1						1		1				1	1
6:00 PM	696	57																
6:15 PM	649	52	1															
6:30 PM	597	48													1			
6:45 PM	556	49			1						1						1	1
7:00 PM	518	45																
7:15 PM	497	50																
7:30 PM	483	50													1			
7:45 PM	461	42			1													
8:00 PM	412	45																
8:15 PM	364	36																
8:30 PM	340	41													1			
8:45 PM	304	43																
9:00 PM	275	34																
9:15 PM	248	36																
9:30 PM	216	28																
9:45 PM	183	25																
HOURS MET			10	0	14	0	0	0	9	2	13	0	6	1	15	0	13	6
WARRANT SATISFIED?			NO		N/A		NO		N/A		NO				NO			

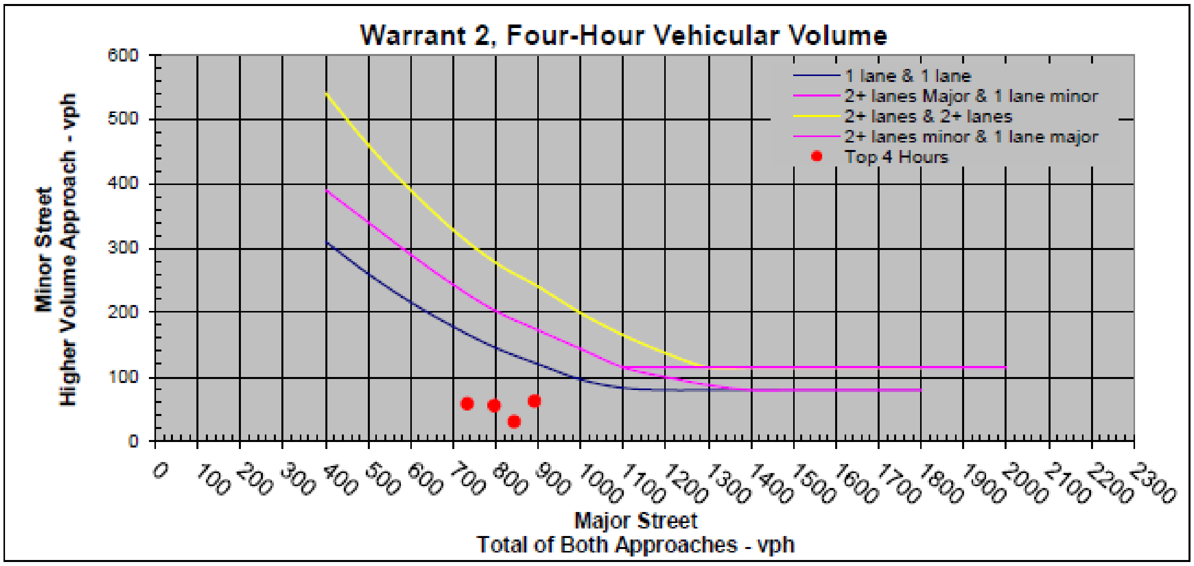
Warrant Met:	**No**
Notes:	

Figure 164:Warrant 1 for Cabrillo Park Drive & Parkcourt Place

Warrant 2: Four-Hour Vehicular Volume

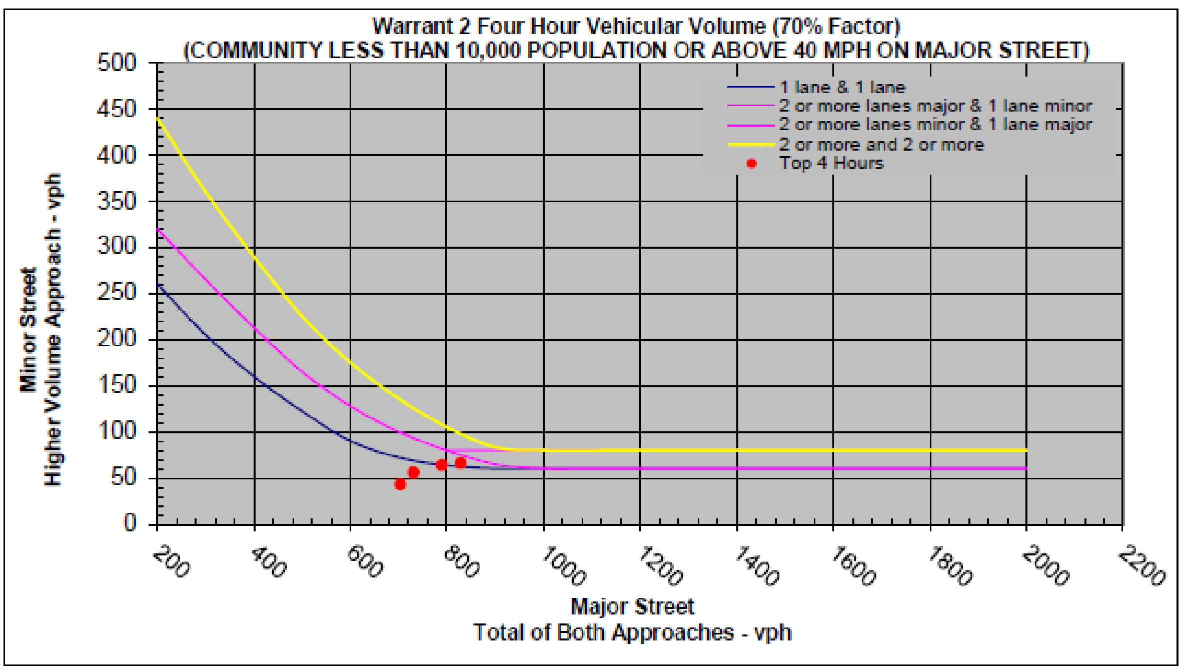
CAMUTCD WARRANT 2, FOUR-HOUR VEHICULAR VOLUME								
Number of Lanes for Moving Traffic on Each Approach			Total Number of Unique Hours Met on Figure 4C-1					0
Major street:	2 or More Lanes		Total Number of Unique Hours Met on Figure 4C-2 (70% Factor)					2
Minor Street:	1 Lane							
Built up Isolated Community with Less Than 10,000 Population or Above 40 MPH on Major Street?								No
Hour Interval Beginning At	Raw Traffic Counts				Total Major Approach Volumes	Highest Actual Minor Street Approach Volumes	Hour Met?	Hour Met? (70% Factor)
	Major - Cabrillo Park Dr		Minor - Parkcourt Pl					
	N-Bound	S-Bound	W-Bound	E-Bound				
6:00 AM	70	182	7	28	252	28		
6:15 AM	86	216	8	30	302	30		
6:30 AM	104	282	7	29	386	29		
6:45 AM	155	369	7	26	524	26		
7:00 AM	199	460	5	27	659	27		
7:15 AM	231	533	7	30	764	30		
7:30 AM	264	579	14	31	843	31		
7:45 AM	268	561	17	37	829	37		
8:00 AM	263	503	20	33	766	33		
8:15 AM	265	466	21	27	731	27		
8:30 AM	244	396	17	28	640	28		
8:45 AM	248	351	13	20	599	20		
9:00 AM	242	318	12	18	560	18		
9:15 AM	254	275	11	22	529	22		
9:30 AM	267	286	13	25	553	25		
9:45 AM	260	280	18	32	540	32		
10:00 AM	283	275	18	37	558	37		
10:15 AM	284	268	20	31	552	31		
10:30 AM	295	263	20	32	558	32		
10:45 AM	324	263	24	30	587	30		
11:00 AM	331	255	29	37	586	37		
11:15 AM	347	281	28	43	628	43		
11:30 AM	355	278	32	42	633	42		
11:45 AM	353	296	35	42	649	42		
12:00 PM	373	327	39	33	700	39		
12:15 PM	358	336	42	27	694	42		
12:30 PM	344	359	43	24	703	43		
12:45 PM	324	353	39	27	677	39		
1:00 PM	318	357	35	30	675	35		
1:15 PM	326	336	31	32	662	32		
1:30 PM	346	312	25	30	658	30		
1:45 PM	370	301	25	30	671	30		
2:00 PM	358	280	33	34	638	34		
2:15 PM	374	305	41	32	679	41		
2:30 PM	381	307	52	40	688	52		
2:45 PM	404	326	56	33	730	56		
3:00 PM	430	357	50	22	787	50		
3:15 PM	450	334	51	22	784	51		
3:30 PM	464	331	52	24	795	52		
3:45 PM	477	319	56	29	796	56		
4:00 PM	498	291	64	35	789	64		Met
4:15 PM	554	293	62	38	847	62		
4:30 PM	588	289	64	32	877	64		
4:45 PM	596	295	63	30	891	63		
5:00 PM	594	292	62	27	886	62		Met
5:15 PM	530	298	66	26	828	66		
5:30 PM	489	291	62	31	780	62		
5:45 PM	459	274	59	33	733	59		
6:00 PM	442	254	57	35	696	57		
6:15 PM	412	237	52	33	649	52		
6:30 PM	369	228	48	30	597	48		
6:45 PM	333	223	49	33	556	49		
7:00 PM	294	224	45	36	518	45		
7:15 PM	277	220	50	33	497	50		
7:30 PM	270	213	50	34	483	50		
7:45 PM	251	210	42	26	461	42		
8:00 PM	233	179	45	25	412	45		

Figure 165: Warrant 2 for Cabrillo Park Drive & Parkcourt Place



Top Hours for Figure 4C-1	Start Time	End Time	Major Street	Minor Street
Top Hour	4:45 PM	5:45 PM	891	63
2nd Highest Hour	3:45 PM	4:45 PM	796	56
3rd Highest Hour	7:30 AM	8:30 AM	843	31
4th Highest Hour	5:45 PM	6:45 PM	733	59

Top Hours for Figure 4C-2	Start Time	End Time	Major Street	Minor Street
Top Hour	5:15 PM	6:15 PM	828	66
2nd Highest Hour	4:00 PM	5:00 PM	789	64
3rd Highest Hour	2:45 PM	3:45 PM	730	56
4th Highest Hour	12:30 PM	1:30 PM	703	43



Are the requirements for Warrant 2 met?: No

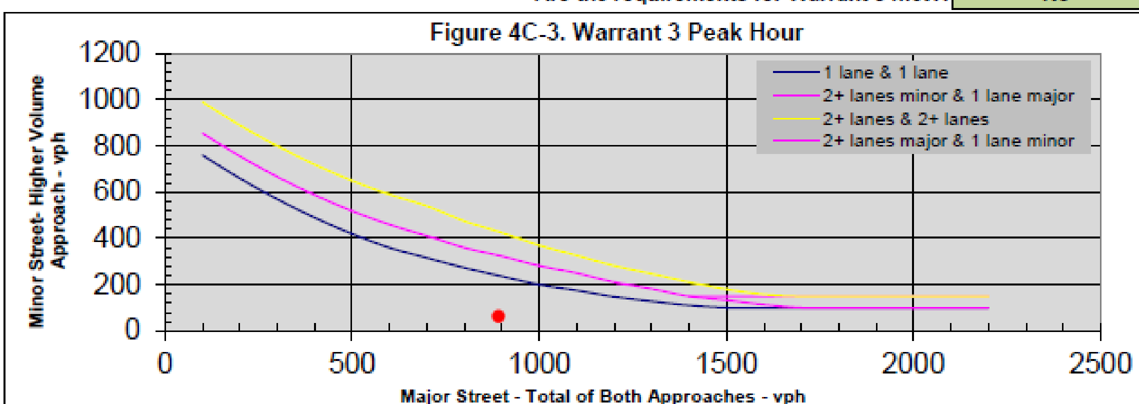
Figure 166: Warrant 2 for Cabrillo Park Drive & Parkcourt Place - Graphs

Warrant 3: Peak Hour

CAMUTCD WARRANT 3, PEAK HOUR			
Number of Lanes for Moving Traffic on Each Approach		Peak Hour Start time	4:45 PM
Major Street:	2 or More Lanes	Peak Hour End Time	5:45 PM
Minor Street:	1 Lane		

Built up Isolated Community with Less Than 10,000 Population or Above 40 MPH on Major Street?	No
Is this signal warrant being applied for an unusual case, such as office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time?	Yes

Indicate whether all three of the following conditions for the same 1 hour (any four consecutive 15-minute periods) of an average day are present*	
Does the total stopped time delay experienced by the traffic on one minor-street approach (one direction only) controlled by a STOP sign equal or exceed 4 vehicle-hours for a one-lane approach or 5 vehicle-hours for a two-lane approach?	Yes
Does the volume on the same minor-street approach (one direction only) equal or exceed 100 vehicles per hour for one moving lane of traffic or 150 vehicles per hour for two moving lanes?	No
Does the total entering volume serviced during the hour equal or exceed 650 vehicles per hour for intersection with three approaches or 800 vehicles per hour for intersections with four or more approaches?	Yes
If applicable, attach all supporting calculations and documentation.	
Are the requirements for Warrant 3 met?:	No



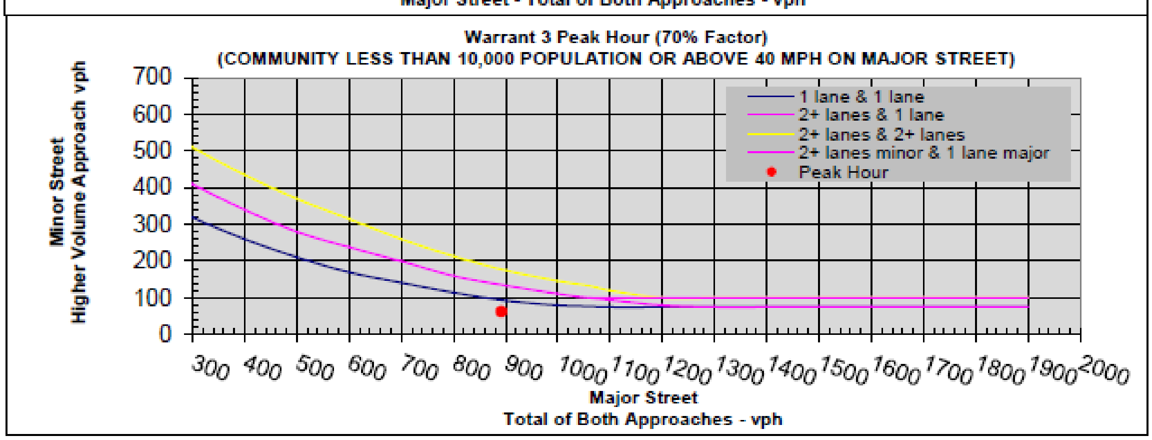


Figure 167: Warrant 3 for Cabrillo Park Drive & Parkcourt Place

Hour Vehicular Volume				
Hour Interval Beginning At	Major Street Combined Vehicles Per Hour (VPH)	Highest Minor Street Approach Vehicles Per Hour (VPH)	Sum of Major Street and Highest Minor Street	Sum of Major Street and Combined Minor Street
6:00 AM	252	28	280	287
6:15 AM	302	30	332	340
6:30 AM	386	29	415	422
6:45 AM	524	26	550	557
7:00 AM	659	27	686	691
7:15 AM	764	30	794	801
7:30 AM	843	31	874	888
7:45 AM	829	37	866	883
8:00 AM	766	33	799	819
8:15 AM	731	27	758	779
8:30 AM	640	28	668	685
8:45 AM	599	20	619	632
9:00 AM	560	18	578	590
9:15 AM	529	22	551	562
9:30 AM	553	25	578	591
9:45 AM	540	32	572	590
10:00 AM	558	37	595	613
10:15 AM	552	31	583	603
10:30 AM	558	32	590	610
10:45 AM	587	30	617	641
11:00 AM	586	37	623	652
11:15 AM	628	43	671	699
11:30 AM	633	42	675	707
11:45 AM	649	42	691	726
12:00 PM	700	39	739	772
12:15 PM	694	42	736	763
12:30 PM	703	43	746	770
12:45 PM	677	39	716	743
1:00 PM	675	35	710	740
1:15 PM	662	32	694	725
1:30 PM	658	30	688	713
1:45 PM	671	30	701	726
2:00 PM	638	34	672	705
2:15 PM	679	41	720	752
2:30 PM	688	52	740	780
2:45 PM	730	56	786	819
3:00 PM	787	50	837	859
3:15 PM	784	51	835	857
3:30 PM	795	52	847	871
3:45 PM	796	56	852	881
4:00 PM	789	64	853	888
4:15 PM	847	62	909	947
4:30 PM	877	64	941	973
4:45 PM	891	63	954	984
5:00 PM	886	62	948	975
5:15 PM	828	66	894	920
5:30 PM	780	62	842	873
5:45 PM	733	59	792	825
6:00 PM	696	57	753	788
6:15 PM	649	52	701	734
6:30 PM	597	48	645	675
6:45 PM	556	49	605	638
7:00 PM	518	45	563	599
7:15 PM	497	50	547	580
7:30 PM	483	50	533	567
7:45 PM	461	42	503	529
8:00 PM	412	45	457	482

Actual Peak Hour Major Traffic Volume	Actual Peak Hour Minor Traffic Volume	Required Peak Hour Minor Traffic Volume for Fig. 4C-3	Required Peak Hour Minor Traffic Volume for Fig. 4C-4
891	63	332.79546	123.7121

Figure 168: Warrant 3 for Cabrillo Park Drive & Parkcourt Place

Warrant 4: Pedestrian Volume

CAMUTCD WARRANT 4, PEDESTRIAN VOLUME

Hour Interval Beginning At	Major Street Combined Vehicles Per Hour (VPH)	Total of All Pedestrians Crossing Major Street Pedestrians Per Hour (PPH)
6:00 AM	252	6
6:15 AM	302	9
6:30 AM	386	15
6:45 AM	524	22
7:00 AM	659	24
7:15 AM	764	27
7:30 AM	843	24
7:45 AM	829	20
8:00 AM	766	20
8:15 AM	731	17
8:30 AM	640	21
8:45 AM	599	21
9:00 AM	560	21
9:15 AM	529	19
9:30 AM	553	14
9:45 AM	540	14
10:00 AM	558	12
10:15 AM	552	11
10:30 AM	558	13
10:45 AM	587	13
11:00 AM	586	13
11:15 AM	628	25
11:30 AM	633	24
11:45 AM	649	23
12:00 PM	700	33
12:15 PM	694	24
12:30 PM	703	25
12:45 PM	677	29
1:00 PM	675	21
1:15 PM	662	17
1:30 PM	658	15
1:45 PM	671	17
2:00 PM	638	15
2:15 PM	679	22
2:30 PM	688	32
2:45 PM	730	29
3:00 PM	787	30
3:15 PM	784	32
3:30 PM	795	28
3:45 PM	796	22
4:00 PM	789	32
4:15 PM	847	29
4:30 PM	877	24
4:45 PM	891	28
5:00 PM	886	28
5:15 PM	828	27
5:30 PM	780	24
5:45 PM	733	22
6:00 PM	696	11
6:15 PM	649	9
6:30 PM	597	8
6:45 PM	556	7
7:00 PM	518	10
7:15 PM	497	8
7:30 PM	483	13
7:45 PM	461	12
8:00 PM	412	10

Built-up Isolated Community With Less Than 10,000 Population or Above 35 MPH on Major Street?	No
15th Percentile Pedestrian Crossing Speed Less than 3.5 f/s?* **If applicable, attach all supporting calculations, documentation, and findings.*	No
If 15th Percentile Pedestrian Crossing Speed is Less than 3.5 f/s, Reduce Criterion by (up to 50%):	10%
Is the distance to the nearest traffic control signal or STOP sign controlling the major street that pedestrians desire to cross less than 300 feet?	No
If the distance to the nearest traffic control signal or STOP sign controlling the major street that pedestrians desire to cross is less than 300 feet, will the proposed traffic control signal restrict the progressive movement of traffic? If applicable, attach supporting justification.	No
Does the intersection meet the 4-Hour Volume?	No
Does the intersection meet the Peak Hour?	No
Are the Requirements for Warrant 4 Satisfied?	**No**

Top Hours for Figure 4C-5	Start Time	End Time	Major Street	Minor Street
Top Hour	4:45 PM	5:45 PM	891	28
2nd Highest Hour	7:30 AM	8:30 AM	843	24
3rd Highest Hour	3:30 PM	4:30 PM	795	28
4th Highest Hour	5:45 PM	6:45 PM	733	22

Top Hours for Figure 4C-6	Start Time	End Time	Major Street	Minor Street
Top Hour	4:00 PM	5:00 PM	789	32
2nd Highest Hour	3:00 PM	4:00 PM	787	30
3rd Highest Hour	5:00 PM	6:00 PM	886	28
4th Highest Hour	7:30 AM	8:30 AM	843	24

Peak Hour Used for Graphs 4C-7 & 4C-8

Top Hour

Start Time	End Time	Major Street	Minor Street
4:45 PM	5:45 PM	891	28

Number of Hours That Met the 4-Hour Criteria 4C-5	0
Number of Hours That Met the 4-Hour Criteria 4C-6	0

Figure 169: Warrant 4 for Cabrillo Park Drive & Parkcourt Place

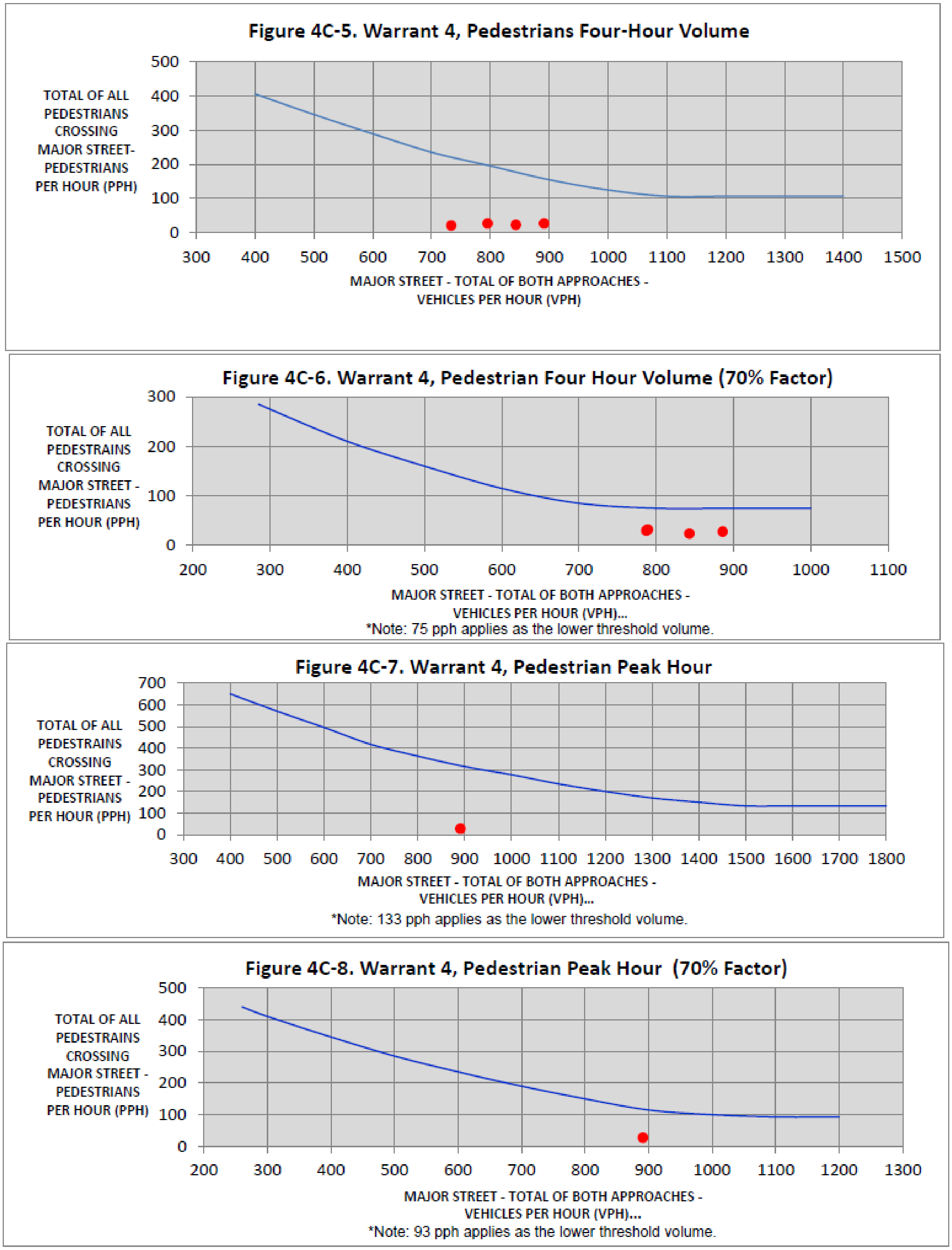


Figure 170: Warrant 4 for Cabrillo Park Drive & Parkcourt Place

Warrant 5: School Crossing

CAMUTCD WARRANT 5, SCHOOL CROSSING	
Do school children (elementary through high school students) cross the major street?	No
Has consideration been given to implement other remedial measures, such as warning signs and flashers, school speed zones, school crossing guards, or a grade-separated crossing?	No
Is the distance to the nearest traffic control signal along the major street less than 300 feet?	No
If the distance to the nearest traffic control signal along the major street is less than 300 feet, will the proposed traffic control signal restrict the progressive movement of traffic?	No
Minimum of 20 schoolchildren during the highest crossing hour?	No
Has a traffic engineering study been conducted to determine the adequacy and frequency of gaps in the vehicular traffic stream as related to the number and size of groups of school children at an established school crossing across the major street?	No
Are the requirements for Warrant 5 met?:	No

Figure 171: Warrant 5 for Cabrillo Park Drive & Parkcourt Place

Warrant 6: Coordinated Signal System

CAMUTCD WARRANT 6, COORDINATED SIGNAL SYSTEM	
On a one-way street or a street that has traffic predominantly in one direction, the adjacent traffic control signals are so far apart that they do not provide the necessary degree of vehicular platooning.	No
On a two-way street, adjacent traffic control signals do not provide the necessary degree of platooning and the proposed and adjacent traffic control signals will collectively provide a progressive operation.	No
**Warrant 6 should not be applied where the resultant spacing of traffic control signals would be less than 1,000 feet.*	
Are the requirements for Warrant 6 met?:	No

Figure 172: Warrant 6 for Cabrillo Park Drive & Parkcourt Place

Warrant 7: Crash Experience

CAMUTCD WARRANT 7, CRASH EXPERIENCE

Built-up Isolated Community With Less Than 10,000 Population or Above 40 mph on Major Street?: No

Number of Lanes for Moving Traffic on Each Approach

Major Street:	2 or More Lanes
Minor Street:	1 Lane

Has adequate trial of alternative with satisfactory observance and enforcement failed to reduce the crash frequency? No

Five or more reportable and/ or non-reportable crashes, of types susceptible to correction by a traffic control signal have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash.* No

**If applicable attach a summary of the crash data analysis used for this criterion*

For each of any 8 hours of an average day, the vehicles per hour given in both the 80% columns of Condition A in Table 4C-1 (See Section 4C.02). No

For each of any 8 hours of an average day, the vehicles per hour given in both the 80% columns of Condition B in Table 4C-1 exists on the major-street and the higher-volume minor-street approach, respectively, to the intersection. No

The volume of pedestrian traffic is not less than 80% of the requirements specified in Warrant 4, the Pedestrian Volume warrant.* No

**If applicable, attach all supporting calculations and documentation*

Are the requirements for Warrant 7 met?: No

Figure 173: Warrant 7 for Cabrillo Park Drive & Parkcourt Place

Warrant 8: Roadway Network

CAMUTCD WARRANT 8, ROADWAY NETWORK

Does the intersection have a total existing, or immediately projected, entering volume of at least 1,000 vehicles per hour during the peak hour of a typical weekday and has 5-year projected traffic volumes, based on an engineering study, that meet one or more of Warrants 1, 2, and 3, during the average weekday?	No
Does the intersection have a total existing or immediately projected entering volume of at least 1,000 vehicles per hour for each of any 5 hours of a non-normal business day (Saturday or Sunday)?	No
Is the major street part of the street or highway system that serves as the principal roadway network for through traffic flow?	No
Does the major street include rural or suburban highways outside, entering, or traversing a city?	No
Does the major street appear as a major route on an official plan, such as a major street plan in an urban area traffic and transportation study?	No
Are the requirements for Warrant 8 met?:	No

Figure 174: Warrant 8 for Cabrillo Park Drive & Parkcourt Place

Warrant 9: Intersection Near a Grade Crossing

CAMUTCD WARRANT 9, INTERSECTION NEAR A GRADE CROSSING

Does the grade crossing exist on an approach controlled by a STOP or Yield sign and the center of the track nearest to the intersection is within 140 feet of the stop line or yield line on the approach?	No
During the highest traffic volume hour during which rail traffic uses the crossing, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the minor-street approach that crosses the track (one direction only, approaching the intersection) falls above the applicable curve in Figure 4C-9 or 4C-10 for the existing combination of approach lanes over the track and the distance.	No
Number of approach lanes on the minor street approach that crosses the track:	0
Clear Storage Distance (D):	N/A feet

Highest Traffic Volume Hour During Which Rail Traffic Uses the Crossing*

*If the rail traffic arrival times are unknown, the highest traffic volume hour of the day should be used.

Major Street Volume (Total of Both Approaches):	N/A vph
Actual Minor-Street Volume (One Direction Only, Approaching the Intersection):	N/A vph
Apply Adjustment Factors to the Minor-Street Volume?:	No

Minor Street Approach Volume Adjustments*

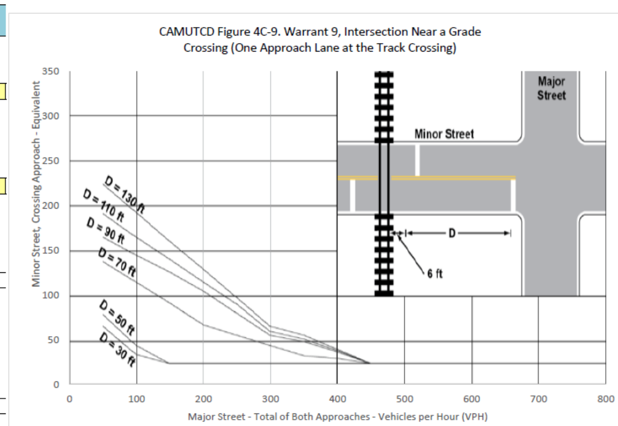
*refers to Section 4C.10 of the CAMUTCD for details on the application of these adjustments

	Inputs	Adjustment Factor
Occurrences of Rail Traffic per Day:	N/A	N/A
% of High-Occupancy Buses (buses with at least 20 people) on Minor Street Approach:	N/A	N/A
% of Tractor-Trailer Trucks on Minor-Street Approach:	N/A	N/A
Adjusted Minor-Street Volume (One Direction Only, Approaching the Intersection		N/A

Traffic Volumes for Figure Comparison

Major Street Volume (Total of Both Approaches):	0
Minor-Street Volume (One Direction Only, Approaching the Intersection):	0
Applicable Figure for Comparison:	Figure 4C-9
Based on Figure 4C-9, is Warrant 9 Met?:*	No

*If point on graph is above the designated line, then Warrant is met.



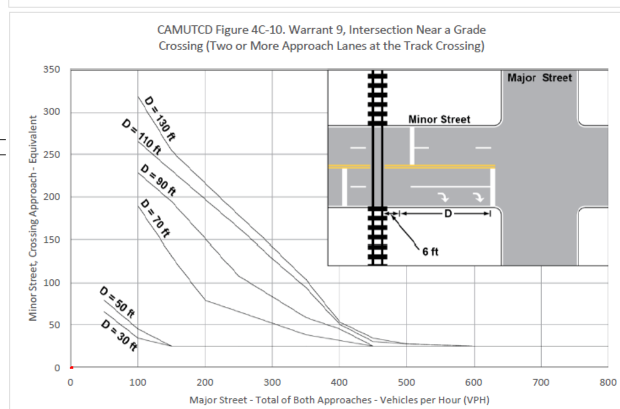


Figure 175: Warrant 9 for Cabrillo Park Drive & Parkcourt Place

Multi-Way Stop Application

Multi-Way Stop Application

CAMUTCD Section 2B.07

	Warranted ?
A. Where traffic control signals are justified, the multi-way stop is an interim measure that can be installed quickly to control traffic while arrangements are being made for the installation of the traffic control signal.	No
B. Five or more reported crashes in a 12-month period that are susceptible to correction by a multiway stop installation. Such crashes include right-turn and left-turn collisions as well as right-angle collisions.	No
C. Minimum Volumes:	
1 The vehicular volume entering the intersection from the major street approaches (total of both approaches) averages at least 300 vehicles per hour for any 8 hours of an average day.	Yes
2 The combined vehicular, pedestrian, and bicycle volume entering the intersection from the minor street approaches (total of both approaches) averages at least 200 units per hour for the same 8 hours, with an average delay to minor-street vehicular traffic of at least 30 seconds per vehicle during the highest hour.* *If this condition is satisfied, there must also be an average delay of at least 30 seconds per vehicle during the peak hour.	No
3 If the 85th-percentile approach speed of the major-street traffic exceeds 40 mph, the minimum volume warrants are 70 percent of the values provided in Items 1 and 2.	No
D. Where no single criterion is satisfied, but where Criteria B, C.1, and C.2 are all satisfied to 80 percent of the minimum values. Criterion C.3 is excluded from this condition.	No
Other criteria that may be considered in an engineering study include:	
A. The need to control left-turn conflicts;	No
B. The need to control vehicle/pedestrian conflicts near locations that generate high pedestrian volumes;	No
C. Locations where a road user, after stopping, cannot see conflicting traffic and is not able to negotiate the intersection unless conflicting cross traffic is also required to stop; and	No
D. An intersection of two residential neighborhood collector (through) streets of similar design and operating characteristics where multi-way stop control would improve traffic operational characteristics of the intersection.	No

Are the requirements for Multi-Way Stop Satisfied?: No

Figure 176: Multi-Way Stop: Cabrillo Park Drive & Parkcourt Place

Lanes Major/ Minor	ADJUSTED VOLUMES		Condition C.1		Condition C.2		Condition D	
	MAJOR	MINOR	100%		70%		80%	
			MAJ.	MIN.	MAJ.	MIN.	MAJ.	MIN.
Required Volumes			300	200	210	140	240	160
6:00 AM	252	41					1	
6:15 AM	302	47	1					
6:30 AM	386	51						
6:45 AM	524	55			1			
7:00 AM	659	56					1	
7:15 AM	764	64	1					
7:30 AM	843	69						
7:45 AM	829	74			1			
8:00 AM	766	73					1	
8:15 AM	731	65	1					
8:30 AM	640	66						
8:45 AM	599	54			1			
9:00 AM	560	51					1	
9:15 AM	529	52	1					
9:30 AM	553	52						
9:45 AM	540	64			1			
10:00 AM	558	67					1	
10:15 AM	552	62	1					
10:30 AM	558	65						
10:45 AM	587	67			1			
11:00 AM	586	79					1	
11:15 AM	628	96	1					
11:30 AM	633	98						
11:45 AM	649	100			1			
12:00 PM	700	105					1	
12:15 PM	694	93	1					
12:30 PM	703	92						
12:45 PM	677	95			1			
1:00 PM	675	86					1	
1:15 PM	662	80	1					
1:30 PM	658	70						
1:45 PM	671	72			1			
2:00 PM	638	82					1	
2:15 PM	679	95	1					
2:30 PM	688	124						
2:45 PM	730	118			1			
3:00 PM	787	102					1	
3:15 PM	784	105	1					
3:30 PM	795	104						
3:45 PM	796	107			1			
4:00 PM	789	131					1	
4:15 PM	847	129	1					
4:30 PM	877	120						
4:45 PM	891	121			1			
5:00 PM	886	117					1	
5:15 PM	828	119	1					
5:30 PM	780	117						
5:45 PM	733	114			1			
6:00 PM	696	103					1	
6:15 PM	649	94	1					
6:30 PM	597	86						
6:45 PM	556	89			1			
7:00 PM	518	91					1	
7:15 PM	497	91	1					
7:30 PM	483	97						
7:45 PM	461	80			1			
8:00 PM	412	80					1	
HOURS MET			**15**	**0**	**16**	**0**	**16**	**0**
WARRANT SATISFIED?			**NO**		**NO**		**NO**	

Intersection: Cabrillo Park Drive & 4th Street

Warrant Summary

STUDY AND ANALYSIS INFORMATION

Municipality:	Santa Ana	Traffic Volumes Obtained By:	The City of Santa Ana
County:	Orange	Analysis Date:	3/12/2023
Caltrans Engineering District:	District 12	Agency/ Company Name Performing Warrant Analysis:	Hayden Robbins

Analysis Information

Data Collection Date:	9/7/2022
Day of the Week:	Wednesday
Is the intersection in a built-up area of an isolated community of <10,000 population?	No
Existing Traffic Signal at intersection:	Yes
Total Number of Approaches at Intersection:	4

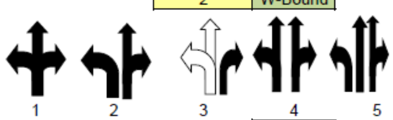
Major Street Information

Major Street Name and Route Number:	Cabrillo Park Dr	
Major Street Approach Direction:	N-Bound S-Bound	
Number of Thru Lanes on Each Major Street Approach:	2	LANE(S)
Speed Limit or 85th Percentile Speed on the Major Street*:	35	MPH

*Unknown assumes below 45 mph

Minor Street Information

Minor Street Name and Route Number:	4th St	
Minor Street Approach Configuration:	5	E-Bound
	2	W-Bound



Number of Thru Lanes on Each Minor Street Approach: 3 LANE(S)

TRAFFIC SIGNAL WARRANT ANALYSIS FINDINGS

	Applicable?	Warrant Satisfied?	Notes and Comments:	Peak Hour
Warrant 1, Eight-Hour Vehicular Volume	Yes	Yes	Condition A was met. Combination of A/B (80%) was met.*	
Warrant 2, Four-Hour Vehicular Volume	Yes	Yes	Figure 4C-1 (100%)	
Warrant 3, Peak Hour	Yes	Yes	Signals installed under Warrant 3 should be traffic actuated.	4:15 PM 5:15 PM
Warrant 4, Pedestrian Volume	No		If this warrant is met, and a traffic control signal is justified by an engineering study, the traffic control signal shall be equipped with pedestrian signal heads complying with the provisions set forth in Chapter 4E of the CAMUTCD.	4:45 PM 5:45 PM
Warrant 5, School Crossing	No		N/A	
Warrant 6, Coordinated Signal System	No		(Shall not be used as the sole warrant in the analysis)	
Warrant 7, Crash Experience	Yes	Yes	If this is the sole warrant, signal must be semi-actuated with control devices which provide proper coordination if installed at an intersection within a coordinated system and normally should be fully traffic actuated if installed at an isolated intersection.	
Warrant 8, Roadway Network	Yes	Yes	(Shall not be used as the sole warrant in the analysis)	
Warrant 9, Intersection Near a Grade Crossing	No		Figure 4C-10	
Multi-Way Stop Warrant	Yes	Yes	May be used as an interim measure if traffic signal warrants are satisfied.	

The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.

Conclusion: Retain Existing Traffic Signal

Notes:

Figure 177: Warrant Summary for Cabrillo Park Drive & 4th Street

Warrant 1: Eight-Hour Vehicular Volume

CAMUTCD WARRANT 1, EIGHT-HOUR VEHICULAR VOLUME

Number of Lanes for Moving Traffic on Each Approach	
Major Street:	2 or More Lanes
Minor Street:	2 or More Lanes

Built up Isolated Community with Less Than 10,000 Population or Above 40 MPH on Major Street? No

*Only applicable after an adequate trial of other alternatives (See section 4C.02.06 of the 2012 CAMUTCD)

Lanes Major/ Minor	Adjusted Volumes		Condition A				Condition B				Combination A/B*							
											Cond. A		Cond. B		Cond. A		Cond. B	
	Major	Minor	100%		70%		100%		70%		80%		80%		56%		56%	
			Maj.	Min.	Maj.	Min.	Maj.	Min.	Maj.	Min.	Maj.	Min.	Maj.	Min.	Maj.	Min.	Maj.	Min.
1 / 1			500	150	350	105	750	75	525	53	400	120	600	60	280	84	420	42
2+ / 1			600	150	420	105	900	75	630	53	480	120	720	60	336	84	504	42
2+ / 2+	X		600	200	420	140	900	100	630	70	480	160	720	80	336	112	504	56
1 / 2+			500	200	350	140	750	100	525	70	400	160	600	80	280	112	420	56
12:00 AM	61	107																
12:15 AM	50	94																
12:30 AM	51	94																
12:45 AM	53	91																
1:00 AM	46	87																
1:15 AM	48	91																
1:30 AM	44	87																
1:45 AM	41	90																
2:00 AM	45	85																
2:15 AM	49	83																
2:30 AM	47	86																
2:45 AM	50	100																
3:00 AM	47	131																
3:15 AM	65	150																
3:30 AM	74	177																
3:45 AM	94	218																
4:00 AM	123	224																
4:15 AM	134	270																
4:30 AM	174	303																
4:45 AM	208	345																
5:00 AM	248	455																
5:15 AM	291	505																
5:30 AM	328	570																
5:45 AM	369	624													1	1		
6:00 AM	409	630																
6:15 AM	472	700			1	1												
6:30 AM	566	753									1	1					1	1
6:45 AM	722	815	1	1					1	1			1	1	1	1		
7:00 AM	918	968					1	1										
7:15 AM	1037	1088			1	1												
7:30 AM	1112	1240									1	1					1	1
7:45 AM	1092	1355	1	1					1	1			1	1	1	1		
8:00 AM	1010	1329					1	1										
8:15 AM	954	1267			1	1												
8:30 AM	867	1142									1	1					1	1
8:45 AM	807	1012	1	1					1	1			1	1	1	1		

Figure 178: Warrant 1 for Cabrillo Park Drive & 4th Street

9:00 AM	737	975																
9:15 AM	691	939			1	1												
9:30 AM	681	909									1	1					1	1
9:45 AM	679	878	1	1					1	1					1	1		
10:00 AM	689	851																
10:15 AM	692	891			1	1												
10:30 AM	698	935									1	1					1	1
10:45 AM	712	1000	1	1					1	1					1	1		
11:00 AM	725	1019											1	1				
11:15 AM	763	1027			1	1												
11:30 AM	796	1042									1	1					1	1
11:45 AM	838	1014	1	1					1	1					1	1		
12:00 PM	905	1022					1	1					1	1				
12:15 PM	916	1032			1	1												
12:30 PM	904	1019									1	1					1	1
12:45 PM	871	1080	1	1					1	1					1	1		
1:00 PM	857	1099											1	1				
1:15 PM	839	1080			1	1												
1:30 PM	856	1101									1	1					1	1
1:45 PM	856	1068	1	1					1	1					1	1		
2:00 PM	798	1109											1	1				
2:15 PM	882	1206			1	1												
2:30 PM	911	1295					1	1			1	1					1	1
2:45 PM	967	1323	1	1					1	1					1	1		
3:00 PM	1091	1404											1	1				
3:15 PM	1075	1406			1	1												
3:30 PM	1087	1484					1	1			1	1					1	1
3:45 PM	1099	1509	1	1					1	1					1	1		
4:00 PM	1069	1471											1	1				
4:15 PM	1075	1541			1	1												
4:30 PM	1075	1494					1	1			1	1					1	1
4:45 PM	1065	1463	1	1					1	1					1	1		
5:00 PM	1014	1457											1	1				
5:15 PM	958	1305			1	1												
5:30 PM	892	1268									1	1					1	1
5:45 PM	820	1194	1	1					1	1					1	1		
6:00 PM	792	1109											1	1				
6:15 PM	737	1027			1	1												
6:30 PM	678	905									1	1					1	1
6:45 PM	653	821	1	1					1	1					1	1		
7:00 PM	610	748																
7:15 PM	603	700			1	1												
7:30 PM	603	647									1	1					1	1
7:45 PM	566	615													1	1		
8:00 PM	500	579																
8:15 PM	437	529			1	1												
8:30 PM	411	501																
8:45 PM	384	461													1	1		
9:00 PM	359	427																
9:15 PM	320	411																
9:30 PM	272	382																
9:45 PM	226	327																
HOURS MET			**13**	**13**	**15**	**15**	**6**	**6**	**13**	**13**	**14**	**14**	**11**	**11**	**16**	**16**	**14**	**14**
WARRANT SATISFIED?			**YES**		**N/A**		**NO**		**N/A**		**YES**				**YES**			

Warrant Met: Yes

Notes: Condition A was met. Combination of A/B (80%) was met.*

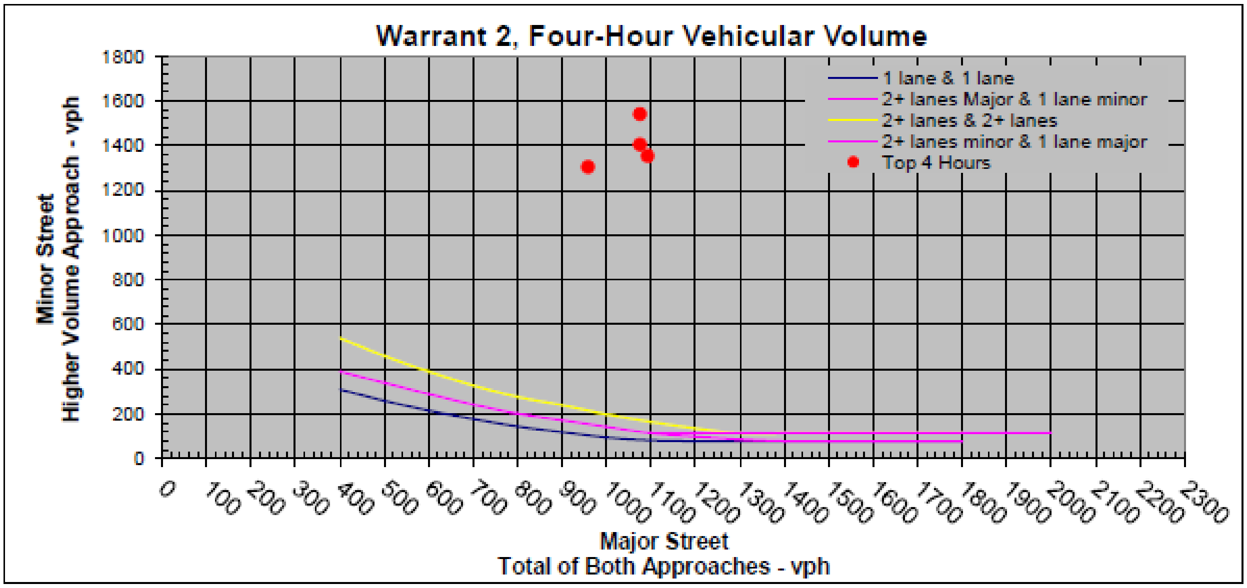
Figure 179: Warrant 1 for Cabrillo Park Drive & 4th Street

Warrant 2: Four-Hour Vehicular Volume

CAMUTCD WARRANT 2, FOUR-HOUR VEHICULAR VOLUME			
Number of Lanes for Moving Traffic on Each Approach		Total Number of Unique Hours Met on Figure 4C-1	17
Major street:	2 or More Lanes	Total Number of Unique Hours Met on Figure 4C-2 (70% Factor)	17
Minor Street:	2 or More Lanes		
Built up Isolated Community with Less Than 10,000 Population or Above 40 MPH on Major Street?			No

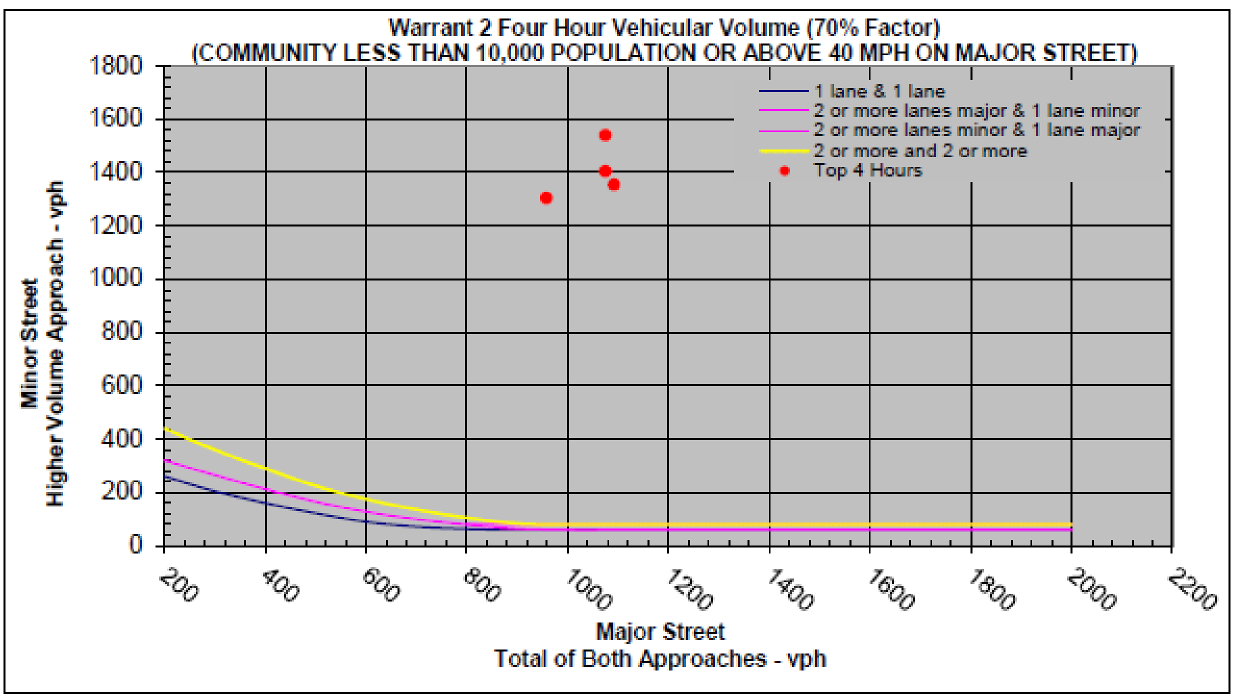
Hour Interval Beginning At	Raw Traffic Counts				Total Major Approach Volumes	Highest Actual Minor Street Approach Volumes	Hour Met?	Hour Met? (70% Factor)
	Major - Cabrillo Park Dr		Minor - E 4th St					
	N-Bound	S-Bound	W-Bound	E-Bound				
6:00 AM	190	219	623	630	409	630	Met	Met
6:15 AM	205	267	667	700	472	700		
6:30 AM	216	350	726	753	566	753		
6:45 AM	262	460	798	815	722	815		
7:00 AM	337	581	913	968	918	968	Met	Met
7:15 AM	379	658	986	1088	1037	1088		
7:30 AM	414	698	989	1240	1112	1240		
7:45 AM	408	684	952	1355	1092	1355		
8:00 AM	395	615	887	1329	1010	1329	Met	Met
8:15 AM	366	588	840	1267	954	1267		
8:30 AM	339	528	850	1142	867	1142		
8:45 AM	336	471	841	1012	807	1012		
9:00 AM	318	419	842	975	737	975	Met	Met
9:15 AM	340	351	827	939	691	939		
9:30 AM	352	329	804	909	681	909		
9:45 AM	362	317	814	878	679	878		
10:00 AM	369	320	805	851	689	851	Met	Met
10:15 AM	384	308	840	891	692	891		
10:30 AM	388	310	865	935	698	935		
10:45 AM	407	305	865	1000	712	1000		
11:00 AM	423	302	873	1019	725	1019	Met	Met
11:15 AM	426	337	894	1027	763	1027		
11:30 AM	442	354	904	1042	796	1042		
11:45 AM	448	390	919	1014	838	1014		
12:00 PM	486	419	940	1022	905	1022	Met	Met
12:15 PM	485	431	969	1032	916	1032		
12:30 PM	476	428	1006	1019	904	1019		
12:45 PM	459	412	1025	1080	871	1080		
1:00 PM	438	419	1033	1099	857	1099	Met	Met
1:15 PM	437	402	1026	1080	839	1080		
1:30 PM	454	402	984	1101	856	1101		
1:45 PM	468	388	1053	1068	856	1068		
2:00 PM	436	362	1109	1066	798	1109	Met	Met
2:15 PM	484	398	1206	1079	882	1206		
2:30 PM	501	410	1295	1088	911	1295		
2:45 PM	531	436	1323	1102	967	1323		
3:00 PM	600	491	1404	1122	1091	1404	Met	Met
3:15 PM	602	473	1406	1160	1075	1406		
3:30 PM	625	462	1484	1149	1087	1484		
3:45 PM	634	465	1509	1136	1099	1509		
4:00 PM	637	432	1471	1102	1069	1471	Met	Met
4:15 PM	659	416	1541	1118	1075	1541		
4:30 PM	672	403	1494	1126	1075	1494		
4:45 PM	675	390	1463	1126	1065	1463		
5:00 PM	653	361	1457	1115	1014	1457	Met	Met
5:15 PM	599	359	1305	1073	958	1305		
5:30 PM	549	343	1268	1045	892	1268		
5:45 PM	502	318	1194	1012	820	1194		
6:00 PM	493	299	1109	977	792	1109	Met	Met
6:15 PM	467	270	1027	907	737	1027		
6:30 PM	427	251	905	833	678	905		
6:45 PM	415	238	821	761	653	821		
7:00 PM	378	232	748	692	610	748	Met	Met
7:15 PM	373	230	700	657	603	700		
7:30 PM	374	229	640	647	603	647		
7:45 PM	344	222	591	615	566	615		
8:00 PM	309	191	537	579	500	579	Met	Met

Figure 180: Warrant 2 for Cabrillo Park Drive & 4th Street



Top Hours for Figure 4C-1	Start Time	End Time	Major Street	Minor Street
Top Hour	4:15 PM	5:15 PM	1075	1541
2nd Highest Hour	3:15 PM	4:15 PM	1075	1406
3rd Highest Hour	7:45 AM	8:45 AM	1092	1355
4th Highest Hour	5:15 PM	6:15 PM	958	1305

Top Hours for Figure 4C-2	Start Time	End Time	Major Street	Minor Street
Top Hour	4:15 PM	5:15 PM	1075	1541
2nd Highest Hour	3:15 PM	4:15 PM	1075	1406
3rd Highest Hour	7:45 AM	8:45 AM	1092	1355
4th Highest Hour	5:15 PM	6:15 PM	958	1305



Are the requirements for Warrant 2 met?: Yes

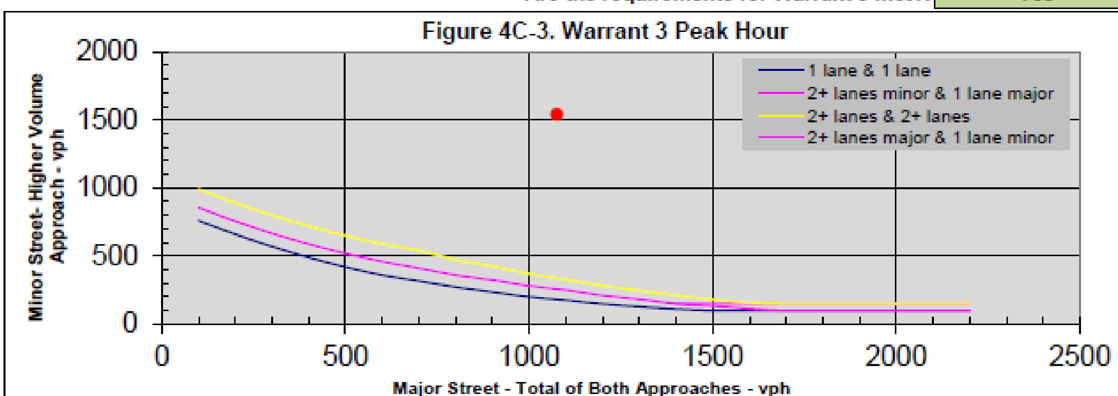
Figure 181: Warrant 2 for Cabrillo Park Drive & 4th Street

Warrant 3: Peak Hour

CAMUTCD WARRANT 3, PEAK HOUR			
Number of Lanes for Moving Traffic on Each Approach		Peak Hour Start time	4:15 PM
Major Street:	2 or More Lanes	Peak Hour End Time	5:15 PM
Minor Street:	2 or More Lanes		

Built up Isolated Community with Less Than 10,000 Population or Above 40 MPH on Major Street?	No
Is this signal warrant being applied for an unusual case, such as office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time?	Yes

Indicate whether all three of the following conditions for the same 1 hour (any four consecutive 15-minute periods) of an average day are present*	
Does the total stopped time delay experienced by the traffic on one minor-street approach (one direction only) controlled by a STOP sign equal or exceed 4 vehicle-hours for a one-lane approach or 5 vehicle-hours for a two-lane approach?	Yes
Does the volume on the same minor-street approach (one direction only) equal or exceed 100 vehicles per hour for one moving lane of traffic or 150 vehicles per hour for two moving lanes?	Yes
Does the total entering volume serviced during the hour equal or exceed 650 vehicles per hour for intersection with three approaches or 800 vehicles per hour for intersections with four or more approaches?	Yes
If applicable, attach all supporting calculations and documentation.	
Are the requirements for Warrant 3 met?:	Yes



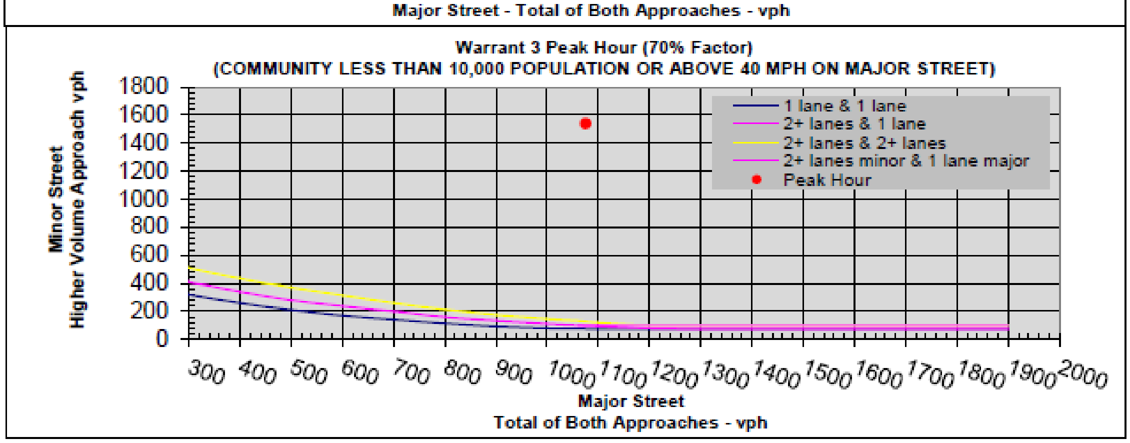


Figure 182: Warrant 3 for Cabrillo Park Drive & 4th Street

Warrant 4: Pedestrian Volume

CAMUTCD WARRANT 4, PEDESTRIAN VOLUME

Hour Interval Beginning At	Major Street Combined Vehicles Per Hour (VPH)	Total of All Pedestrians Crossing Major Street Pedestrians Per Hour (PPH)
6:00 AM	409	9
6:15 AM	472	11
6:30 AM	566	13
6:45 AM	722	21
7:00 AM	918	24
7:15 AM	1037	22
7:30 AM	1112	22
7:45 AM	1092	14
8:00 AM	1010	12
8:15 AM	954	10
8:30 AM	867	7
8:45 AM	807	8
9:00 AM	737	11
9:15 AM	691	16
9:30 AM	681	17
9:45 AM	679	22
10:00 AM	689	27
10:15 AM	692	27
10:30 AM	698	32
10:45 AM	712	34
11:00 AM	725	27
11:15 AM	763	36
11:30 AM	796	46
11:45 AM	838	58
12:00 PM	905	66
12:15 PM	916	54
12:30 PM	904	39
12:45 PM	871	19
1:00 PM	857	10
1:15 PM	839	8
1:30 PM	856	4
1:45 PM	856	4
2:00 PM	798	3
2:15 PM	882	3
2:30 PM	911	5
2:45 PM	967	3
3:00 PM	1091	5
3:15 PM	1075	9
3:30 PM	1087	13
3:45 PM	1099	20
4:00 PM	1069	25
4:15 PM	1075	38
4:30 PM	1075	43
4:45 PM	1065	55
5:00 PM	1014	61
5:15 PM	958	48
5:30 PM	892	46
5:45 PM	820	30
6:00 PM	792	24
6:15 PM	737	21
6:30 PM	678	12
6:45 PM	653	10
7:00 PM	610	3
7:15 PM	603	3
7:30 PM	603	4
7:45 PM	566	3
8:00 PM	500	3

Built-up Isolated Community With Less Than 10,000 Population or Above 35 MPH on Major Street?	No
15th Percentile Pedestrian Crossing Speed Less than 3.5 f/s?* **If applicable, attach all supporting calculations, documentation, and findings.*	No
If 15th Percentile Pedestrian Crossing Speed is Less than 3.5 f/s, Reduce Criterion by (up to 50%):	25%
Is the distance to the nearest traffic control signal or STOP sign controlling the major street that pedestrians desire to cross less than 300 feet?	Yes
If the distance to the nearest traffic control signal or STOP sign controlling the major street that pedestrians desire to cross is less than 300 feet, will the proposed traffic control signal restrict the progressive movement of traffic? If applicable, attach supporting justification.	No
Does the intersection meet the 4-Hour Volume?	No
Does the intersection meet the Peak Hour?	No
Are the Requirements for Warrant 4 Satisfied?	N/A

Top Hours for Figure 4C-5	Start Time	End Time	Major Street	Minor Street
Top Hour	4:45 PM	5:45 PM	1065	55
2nd Highest Hour	7:30 AM	8:30 AM	1112	22
3rd Highest Hour	12:00 PM	1:00 PM	905	66
4th Highest Hour	3:45 PM	4:45 PM	1099	20

Top Hours for Figure 4C-6	Start Time	End Time	Major Street	Minor Street
Top Hour	12:00 PM	1:00 PM	905	66
2nd Highest Hour	5:00 PM	6:00 PM	1014	61
3rd Highest Hour	4:00 PM	5:00 PM	1069	25
4th Highest Hour	7:00 AM	8:00 AM	918	24

Peak Hour Used for Graphs 4C-7 & 4C-8			
Top Hour			
Start Time	End Time	Major Street	Minor Street
4:45 PM	5:45 PM	1065	55

Number of Hours That Met the 4-Hour Criteria 4C-5	0
Number of Hours That Met the 4-Hour Criteria 4C-6	0

Figure 183: Warrant 4 for Cabrillo Park Drive & 4th Street

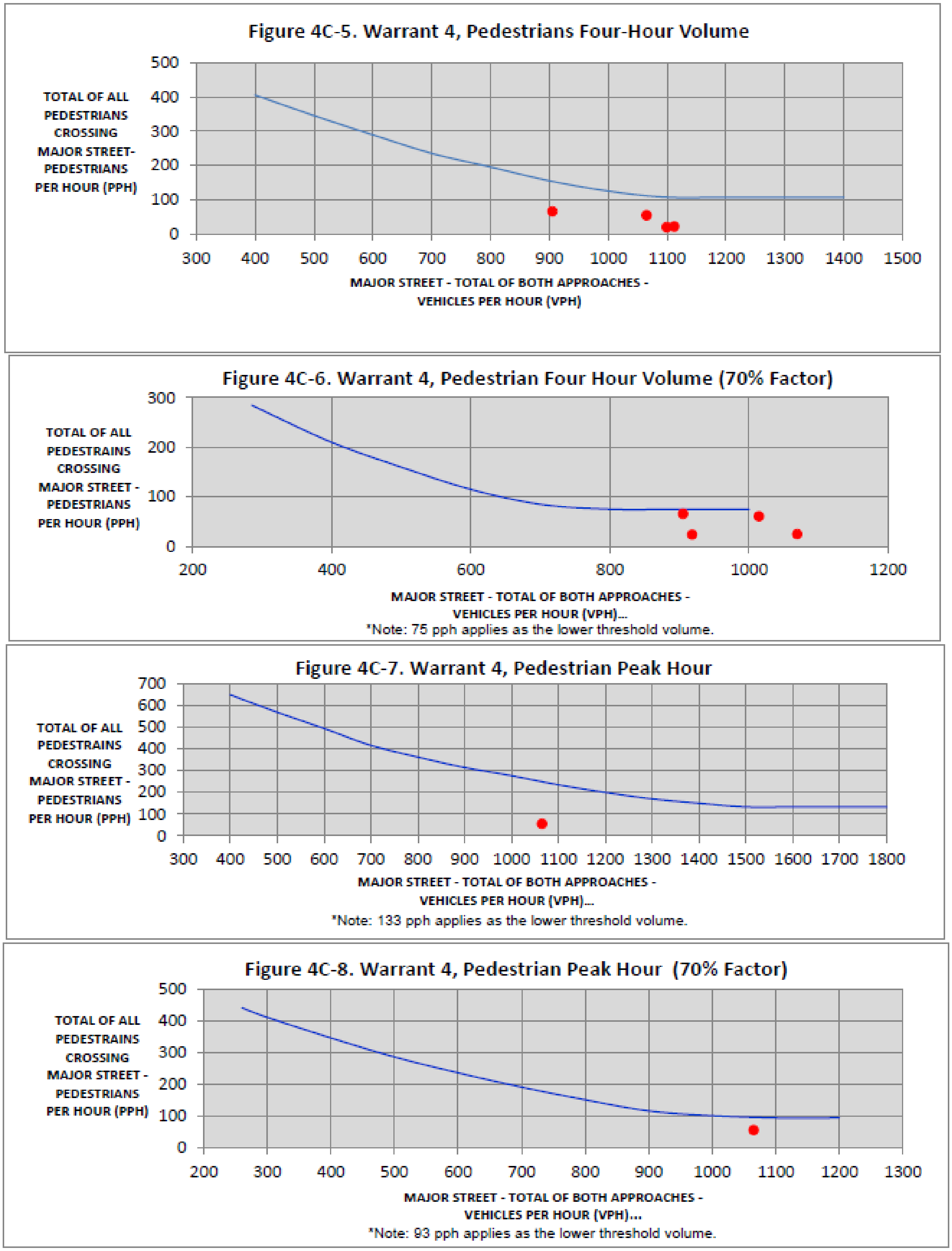


Figure 184: Warrant 4 for Cabrillo Park Drive & 4th Street

Warrant 5: School Crossing

CAMUTCD WARRANT 5, SCHOOL CROSSING

Do school children (elementary through high school students) cross the major street?	No
Has consideration been given to implement other remedial measures, such as warning signs and flashers, school speed zones, school crossing guards, or a grade-separated crossing?	No
Is the distance to the nearest traffic control signal along the major street less than 300 feet?	No
If the distance to the nearest traffic control signal along the major street is less than 300 feet, will the proposed traffic control signal restrict the progressive movement of traffic?	No
Minimum of 20 schoolchildren during the highest crossing hour?	No
Has a traffic engineering study been conducted to determine the adequacy and frequency of gaps in the vehicular traffic stream as related to the number and size of groups of school children at an established school crossing across the major street?	No

Are the requirements for Warrant 5 met?: No

Figure 185: Warrant 5 for Cabrillo Park Drive & 4th Street

Warrant 6: Coordinated Signal System

CAMUTCD WARRANT 6, COORDINATED SIGNAL SYSTEM

On a one-way street or a street that has traffic predominantly in one direction, the adjacent traffic control signals are so far apart that they do not provide the necessary degree of vehicular platooning.	No
On a two-way street, adjacent traffic control signals do not provide the necessary degree of platooning and the proposed and adjacent traffic control signals will collectively provide a progressive operation.	No

**Warrant 6 should not be applied where the resultant spacing of traffic control signals would be less than 1,000 feet.*

Are the requirements for Warrant 6 met?: No

Figure 186: Warrant 6 for Cabrillo Park Drive & 4th Street

Warrant 7: Crash Experience

CAMUTCD WARRANT 7, CRASH EXPERIENCE

Built-up Isolated Community With Less Than 10,000 Population or Above 40 mph on Major Street?: No

Number of Lanes for Moving Traffic on Each Approach

Major Street: 2 or More Lanes

Minor Street: 2 or More Lanes

Has adequate trial of alternative with satisfactory observance and enforcement failed to reduce the crash frequency? Yes

Five or more reportable and/ or non-reportable crashes, of types susceptible to correction by a traffic control signal have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash.* Yes

**If applicable attach a summary of the crash data analysis used for this criterion*

For each of any 8 hours of an average day, the vehicles per hour given in both the 80% columns of Condition A in Table 4C-1 (See Section 4C.02). Yes

For each of any 8 hours of an average day, the vehicles per hour given in both the 80% columns of Condition B in Table 4C-1 exists on the major-street and the higher-volume minor-street approach, respectively, to the intersection. Yes

The volume of pedestrian traffic is not less than 80% of the requirements specified in Warrant 4, the Pedestrian Volume warrant.* No

**If applicable, attach all supporting calculations and documentation*

Are the requirements for Warrant 7 met?: Yes

Figure 187: Warrant 7 for Cabrillo Park Drive & 4th Street

Warrant 8: Roadway Network

CAMUTCD WARRANT 8, ROADWAY NETWORK

Does the intersection have a total existing, or immediately projected, entering volume of at least 1,000 vehicles per hour during the peak hour of a typical weekday and has 5-year projected traffic volumes, based on an engineering study, that meet one or more of Warrants 1, 2, and 3, during the average weekday?	Yes
Does the intersection have a total existing or immediately projected entering volume of at least 1,000 vehicles per hour for each of any 5 hours of a non-normal business day (Saturday or Sunday)?	Yes
Is the major street part of the street or highway system that serves as the principal roadway network for through traffic flow?	Yes
Does the major street include rural or suburban highways outside, entering, or traversing a city?	No
Does the major street appear as a major route on an official plan, such as a major street plan in an urban area traffic and transportation study?	No
Are the requirements for Warrant 8 met?:	Yes

Figure 188: Warrant 8 for Cabrillo Park Drive & 4th Street

Warrant 9: Intersection Near a Grade Crossing

CAMUTCD WARRANT 9, INTERSECTION NEAR A GRADE CROSSING

Does the grade crossing exist on an approach controlled by a STOP or Yield sign and the center of the track nearest to the intersection is within 140 feet of the stop line or yield line on the approach?	No
During the highest traffic volume hour during which rail traffic uses the crossing, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the minor-street approach that crosses the track (one direction only, approaching the intersection) falls above the applicable curve in Figure 4C-9 or 4C-10 for the existing combination of approach lanes over the track and the distance.	No
Number of approach lanes on the minor street approach that crosses the track:	0
Clear Storage Distance (D):	N/A feet

Highest Traffic Volume Hour During Which Rail Traffic Uses the Crossing*

If the rail traffic arrival times are unknown, the highest traffic volume hour of the day should be used.

Major Street Volume (Total of Both Approaches):	N/A vph
Actual Minor-Street Volume (One Direction Only, Approaching the Intersection):	N/A vph
Apply Adjustment Factors to the Minor-Street Volume?:	No

Minor Street Approach Volume Adjustments*

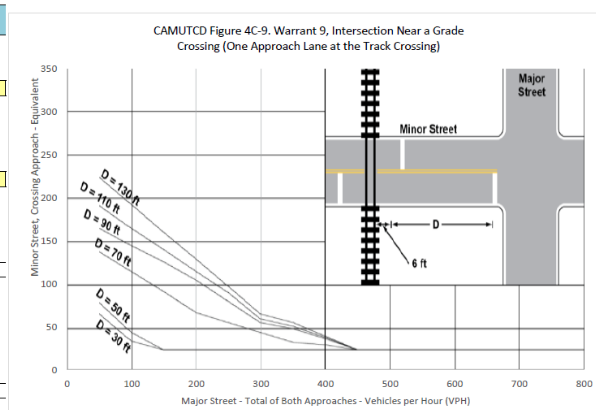
refers to Section 4C.10 of the CAMUTCD for details on the application of these adjustments

	Inputs	Adjustment Factor
Occurrences of Rail Traffic per Day:	N/A	N/A
% of High-Occupancy Buses (buses with at least 20 people) on Minor Street Approach:	N/A	N/A
% of Tractor-Trailer Trucks on Minor-Street Approach:	N/A	N/A
Adjusted Minor-Street Volume (One Direction Only, Approaching the Intersection		N/A

Traffic Volumes for Figure Comparison

Major Street Volume (Total of Both Approaches):	0
Minor-Street Volume (One Direction Only, Approaching the Intersection):	0
Applicable Figure for Comparison:	Figure 4C-9
Based on Figure 4C-9, is Warrant 9 Met?:*	No

If point on graph is above the designated line, then Warrant is met.



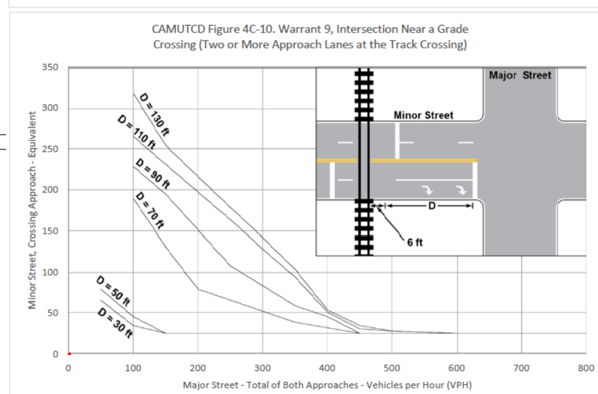


Figure 189: Warrant 9 for Cabrillo Park Drive & 4th Street

Multi-Way Stop Application

Multi-Way Stop Application	
CAMUTCD Section 2B.07	
	Warranted ?
A. Where traffic control signals are justified, the multi-way stop is an interim measure that can be installed quickly to control traffic while arrangements are being made for the installation of the traffic control signal.	Yes
B. Five or more reported crashes in a 12-month period that are susceptible to correction by a multiway stop installation. Such crashes include right-turn and left-turn collisions as well as right-angle collisions.	Yes
C. Minimum Volumes:	
1 The vehicular volume entering the intersection from the major street approaches (total of both approaches) averages at least 300 vehicles per hour for any 8 hours of an average day.	Yes
2 The combined vehicular, pedestrian, and bicycle volume entering the intersection from the minor street approaches (total of both approaches) averages at least 200 units per hour for the same 8 hours, with an average delay to minor-street vehicular traffic of at least 30 seconds per vehicle during the highest hour.* *If this condition is satisfied, there must also be an average delay of at least 30 seconds per vehicle during the peak hour.	Yes
3 If the 85th-percentile approach speed of the major-street traffic exceeds 40 mph, the minimum volume warrants are 70 percent of the values provided in Items 1 and 2.	No
D. Where no single criterion is satisfied, but where Criteria B, C.1, and C.2 are all satisfied to 80 percent of the minimum values. Criterion C.3 is excluded from this condition.	No
Other criteria that may be considered in an engineering study include:	
A. The need to control left-turn conflicts;	Yes
B. The need to control vehicle/pedestrian conflicts near locations that generate high pedestrian volumes;	Yes
C. Locations where a road user, after stopping, cannot see conflicting traffic and is not able to negotiate the intersection unless conflicting cross traffic is also required to stop; and	Yes
D. An intersection of two residential neighborhood collector (through) streets of similar design and operating characteristics where multi-way stop control would improve traffic operational characteristics of the intersection.	Yes
Are the requirements for Multi-Way Stop Satisfied?:	Yes

Figure 190: Multi-Way Stop for Cabrillo Park Drive & 4th Street

Lanes Major/ Minor	ADJUSTED VOLUMES		Condition C.1		Condition C.2		Condition D	
	MAJOR	MINOR	100%		70%		80%	
			MAJ.	MIN.	MAJ.	MIN.	MAJ.	MIN.
Required Volumes			300	200	210	140	240	160
6:00 AM	409	1262			1	1	1	1
6:15 AM	472	1378						
6:30 AM	566	1492	1	1				
6:45 AM	722	1634						
7:00 AM	918	1905			1	1	1	1
7:15 AM	1037	2096						
7:30 AM	1112	2251	1	1				
7:45 AM	1092	2321						
8:00 AM	1010	2228			1	1	1	1
8:15 AM	954	2117						
8:30 AM	867	1999	1	1				
8:45 AM	807	1861						
9:00 AM	737	1828			1	1	1	1
9:15 AM	691	1782						
9:30 AM	681	1730	1	1				
9:45 AM	679	1714						
10:00 AM	689	1683			1	1	1	1
10:15 AM	692	1758						
10:30 AM	698	1832	1	1				
10:45 AM	712	1899						
11:00 AM	725	1919			1	1	1	1
11:15 AM	763	1957						
11:30 AM	796	1992	1	1				
11:45 AM	838	1991						
12:00 PM	905	2028			1	1	1	1
12:15 PM	916	2055						
12:30 PM	904	2064	1	1				
12:45 PM	871	2124						
1:00 PM	857	2142			1	1	1	1
1:15 PM	839	2114						
1:30 PM	856	2089	1	1				
1:45 PM	856	2125						
2:00 PM	798	2178			1	1	1	1
2:15 PM	882	2288						
2:30 PM	911	2388	1	1				
2:45 PM	967	2428						
3:00 PM	1091	2531			1	1	1	1
3:15 PM	1075	2575						
3:30 PM	1087	2646	1	1				
3:45 PM	1099	2665						
4:00 PM	1069	2598			1	1	1	1
4:15 PM	1075	2697						
4:30 PM	1075	2663	1	1				
4:45 PM	1065	2644						
5:00 PM	1014	2633			1	1	1	1
5:15 PM	958	2426						
5:30 PM	892	2359	1	1				
5:45 PM	820	2236						
6:00 PM	792	2110			1	1	1	1
6:15 PM	737	1955						
6:30 PM	678	1750	1	1				
6:45 PM	653	1592						
7:00 PM	610	1443			1	1	1	1
7:15 PM	603	1360						
7:30 PM	603	1291	1	1				
7:45 PM	566	1209						
8:00 PM	500	1119			1	1	1	1
HOURS MET			16	16	18	18	17	17
WARRANT SATISFIED?			YES		YES		YES	

Collision Statistics

Collision diagrams and crash data are important for any intersection to analyze how safe and effective traffic control measures are. We obtained data from the City of Santa Ana as well as Berkley's Transportation Injury Mapping System (TIMS) database (SafeTREC, 2023).

Note: TIMS database did not match the data collected from the City of Santa Ana so we will present both types of data and comment on the discrepancies.

TIMS Database Results

All Collisions in Santa Ana, CA from 2017 - 2022

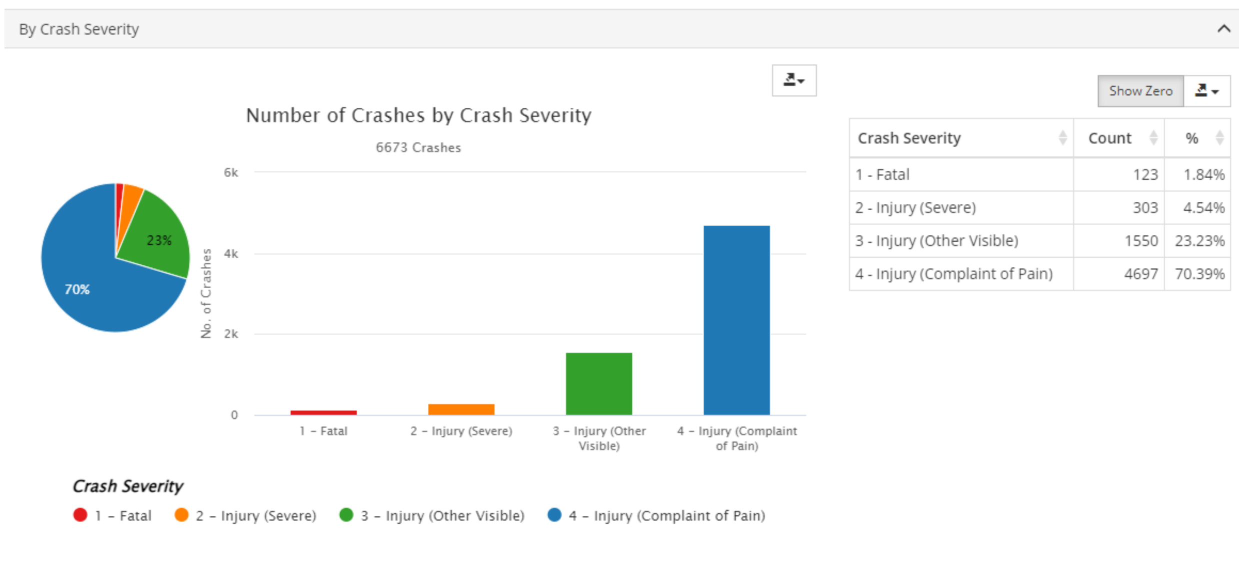
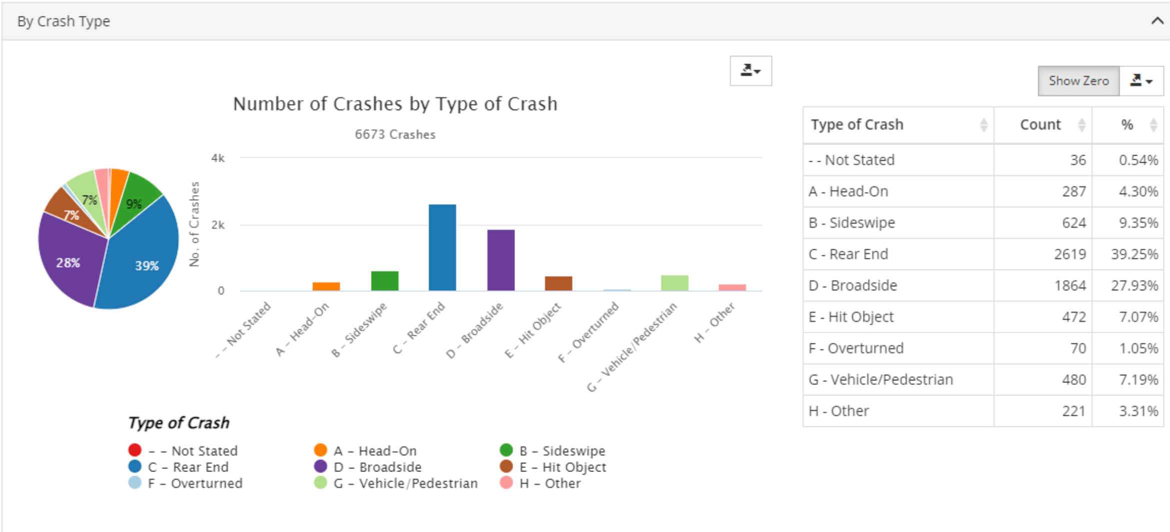


Figure 191: TIMS Number of Crashes by Crash Severity for Santa Ana between 2017 - 2022

As shown in the figure above, there were 6,673 collisions that occurred in the entire city of Santa Ana from 2017 - 2022. 129 victims were killed, 9,368 were injured, 513 (7.7%) involved pedestrians and 386 (5.8%) involved bicyclists. Out of the 6,673 crashes, 123 (1.84%) were fatal, 303 (4.54%) had severe injuries, 15500 (23.23%) had other visible injuries, and 4697 (70.39%) had injuries with complaints of pain.



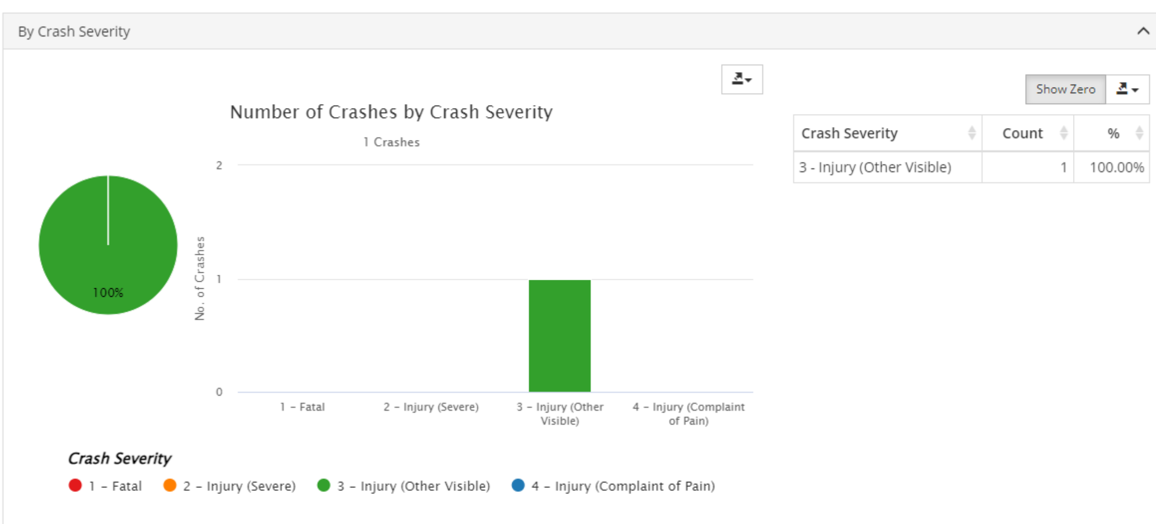
Type of Crash	Count	%
- - Not Stated	36	0.54%
A - Head-On	287	4.30%
B - Sideswipe	624	9.35%
C - Rear End	2619	39.25%
D - Broadside	1864	27.93%
E - Hit Object	472	7.07%
F - Overturned	70	1.05%
G - Vehicle/Pedestrian	480	7.19%
H - Other	221	3.31%

Figure 192: City of Santa Ana Number of Crashes by Type of Crash

The most common types of crashes throughout the city of Santa Ana were Rear-End crashes that accounted for 39.25% of all crashes. As the name suggests, rear-end collisions involve the front of one vehicle colliding with the rear end of another vehicle. Rear-ends can be the result of hesitant drivers attempting to make a left-turn but do not have proper sight line distance to see if there's oncoming traffic in the opposing direction.

Cabrillo Park Drive & Parkcourt Place

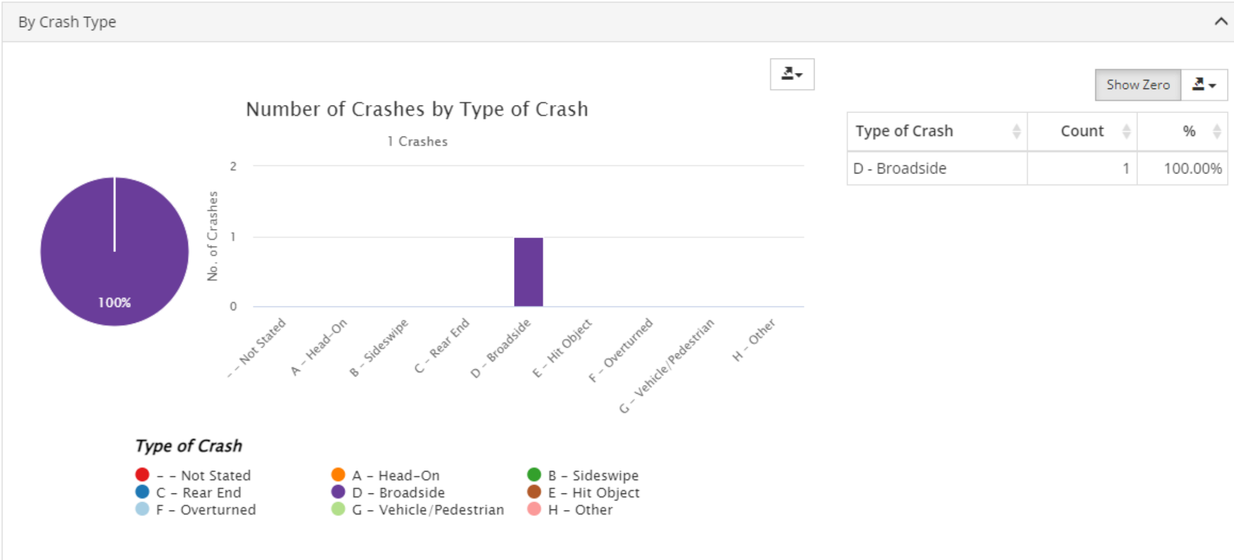
Crash Summary



Crash Severity	Count	%
3 - Injury (Other Visible)	1	100.00%

Figure 193: Number of Crashes by Crash Severity - Cabrillo Park Drive & Parkcourt Place

Using TIMs, there was only 1 reported accident that resulted in injury from 2017 - 2022.



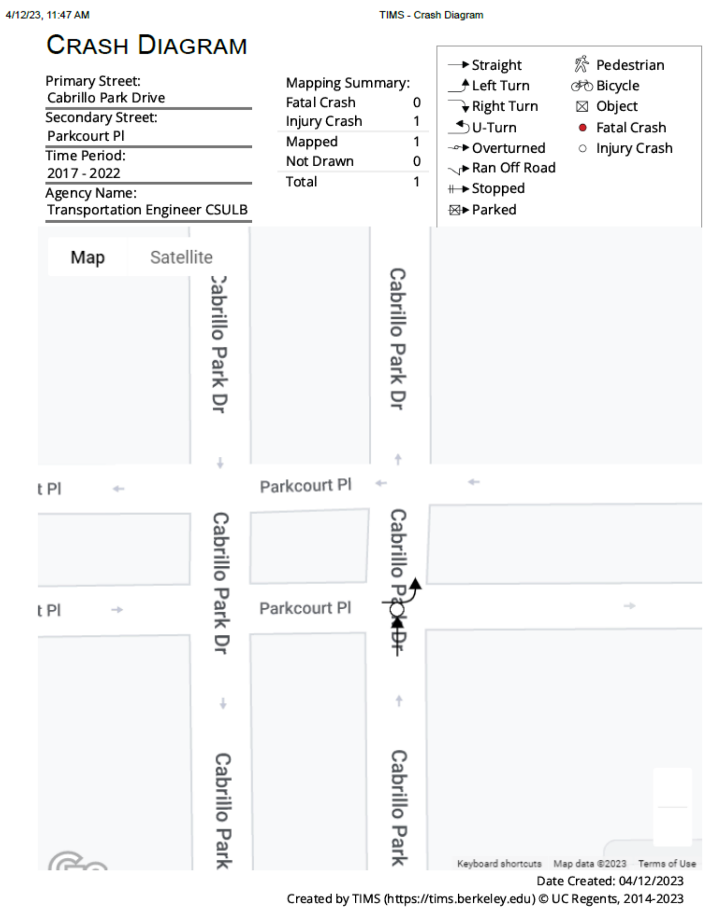
Type of Crash	Count	%
D - Broadside	1	100.00%

Figure 194: Number of Crashes by Crash Type - Cabrillo Park Drive & Parkcourt Place

The reported accident was the result of a Broadside collision. According to Boohoff Law, broadside collisions "most frequently occur at intersections when the front end of one vehicle strikes the passenger side of another vehicle at a right angle" (Boohoff Law, n.d.).

Collision Diagrams

Table 132: TIMS Collision Diagrams - Cabrillo Park Drive & Parkcourt Place

<table>
<tr><th>Map View</th><th>Satellite View</th></tr>
<tr><td>


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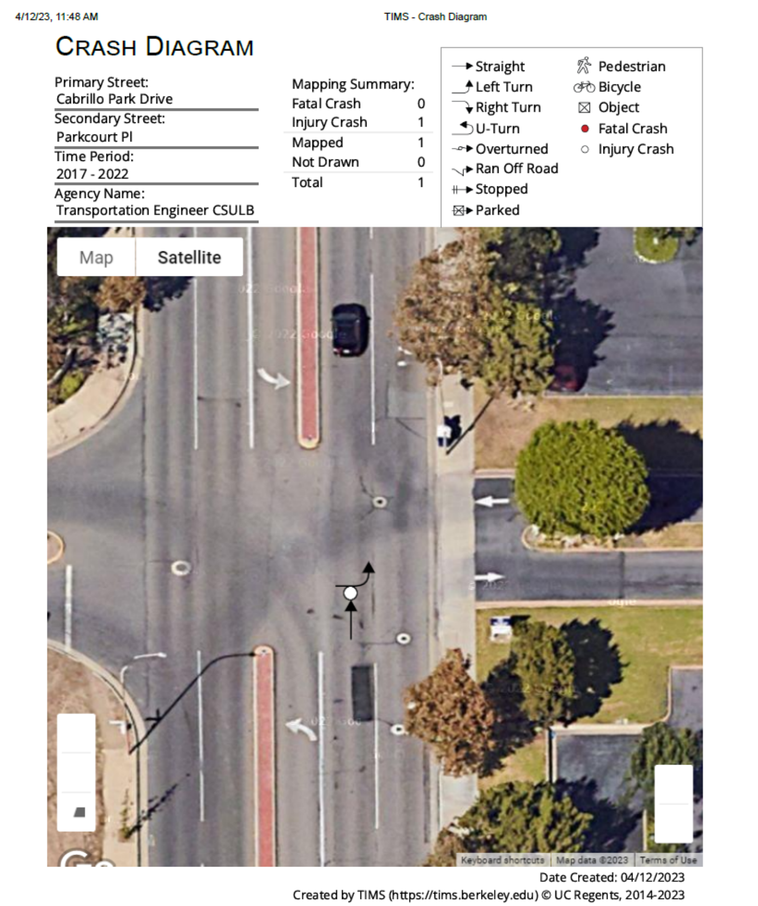

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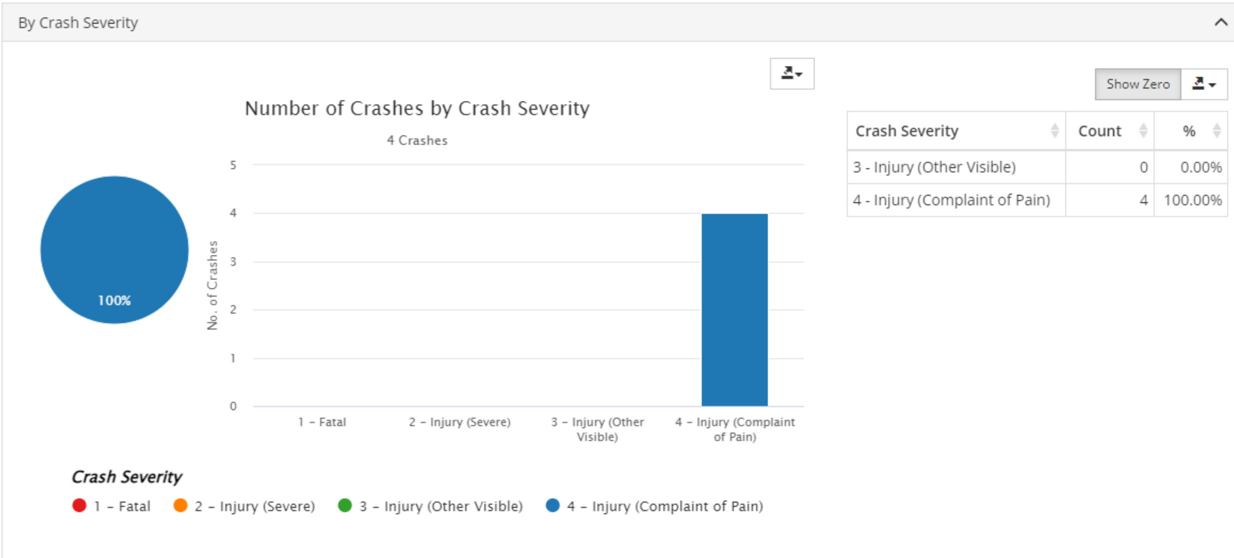
Cabrillo Park Drive & E Fruit Street

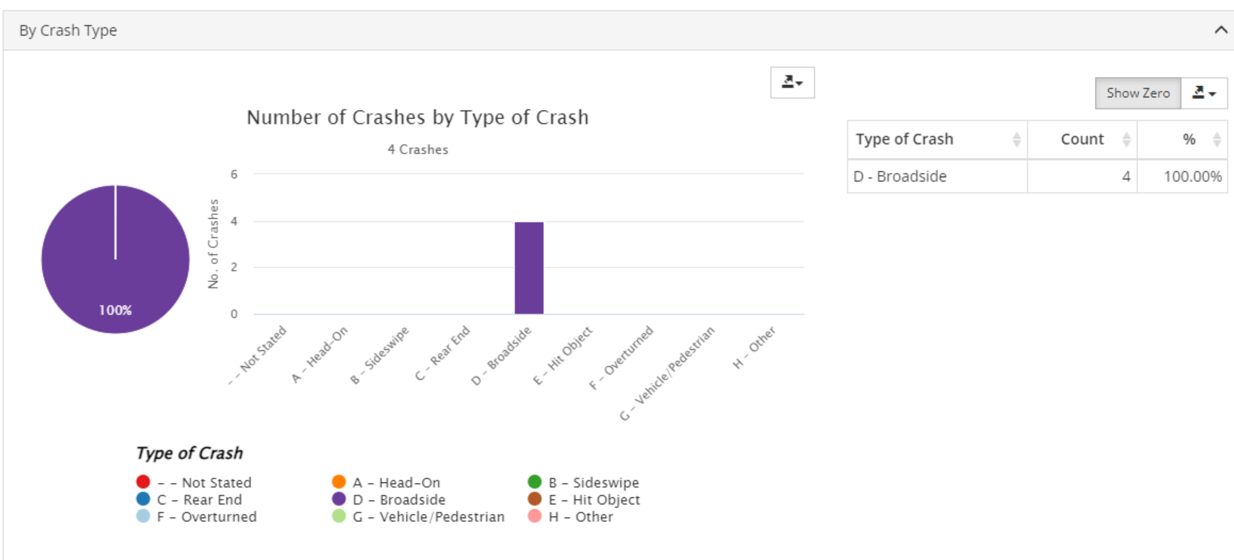
Crash Summary



Crash Severity	Count	%
3 - Injury (Other Visible)	0	0.00%
4 - Injury (Complaint of Pain)	4	100.00%

Figure 195: Number of Crashes by Crash Severity - Cabrillo Park Drive & E Fruit Street

Cabrillo Park Drive and E Fruit Street has an existing all-way stop for all 4 approaches. TIMs reported there were 4 accidents resulting in injury from 2017 - 2022.



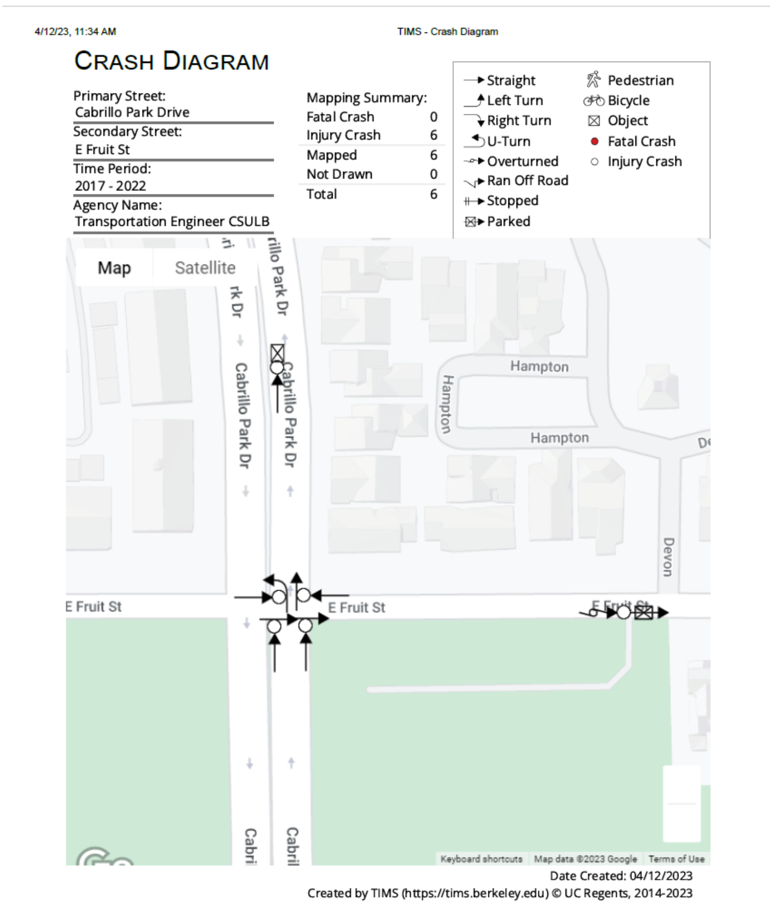
Type of Crash	Count	%
D - Broadside	4	100.00%

Figure 196: Number of Crashes by Type of Crash - Cabrillo Park Drive & E Fruit Street

All 4 accidents were the result of Broadside collisions.

Collision Diagrams

Table 133: TIMS Collision Diagrams - Cabrillo Park Drive & E Fruit Street

<table>
<tr><th>Map View</th><th>Satellite View</th></tr>
<tr>
<td>


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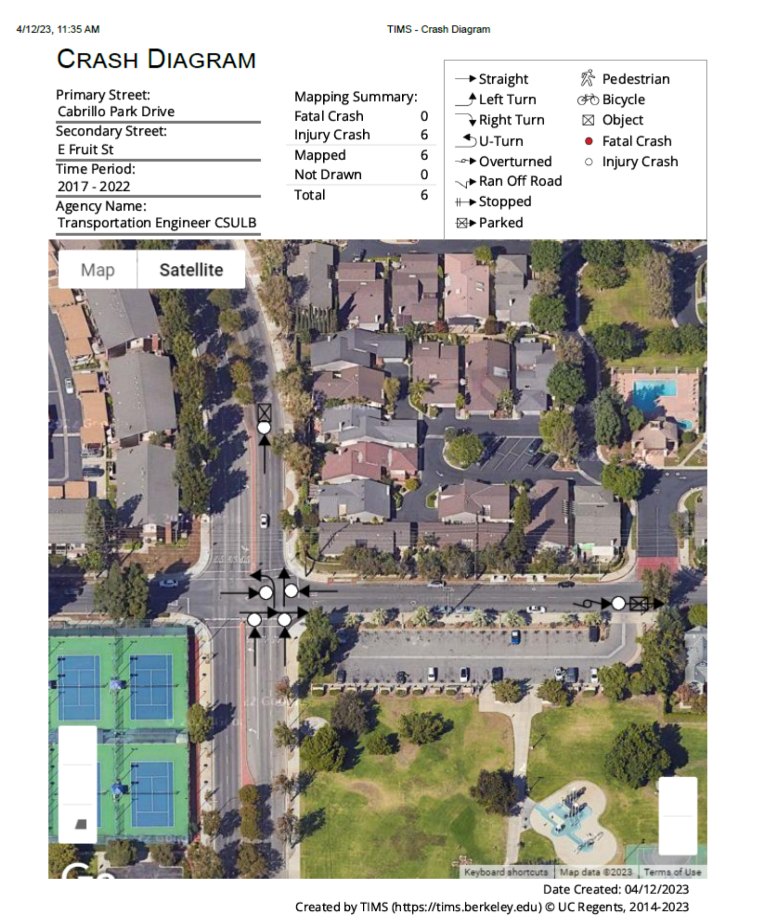

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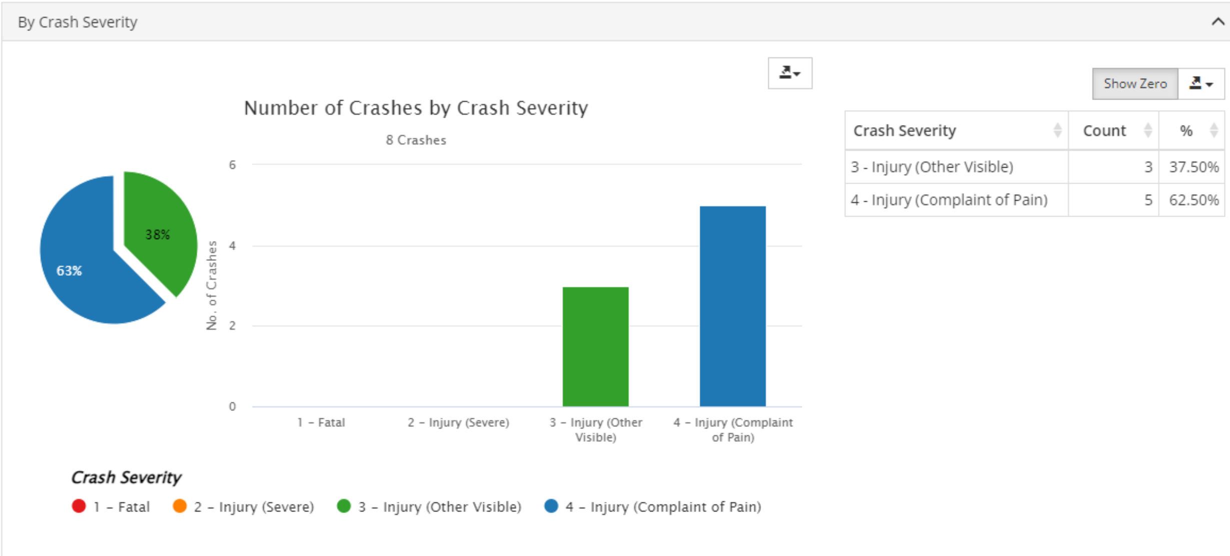
Cabrillo Park Drive & E 4th Street

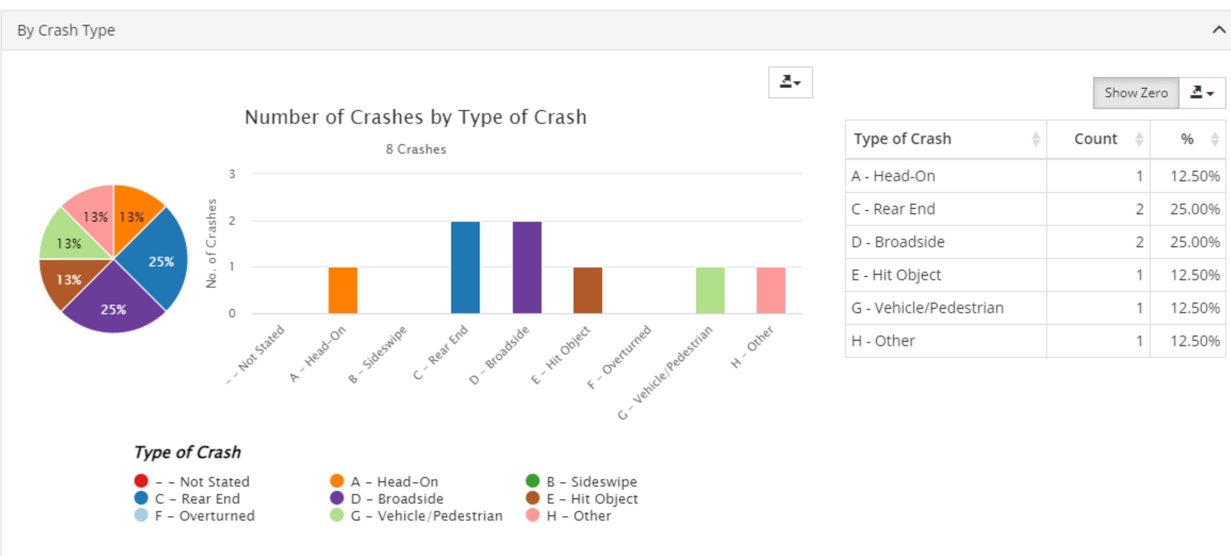
Crash Summary



Crash Severity	Count	%
3 - Injury (Other Visible)	3	37.50%
4 - Injury (Complaint of Pain)	5	62.50%

Figure 197: Number of Crashes by Severity - Cabrillo Park Drive & E 4th Street

There were 8 crashes that resulted in injury for the intersection of Cabrillo Park Drive and E 4th Street. This is the only analyzed intersection that is signalized. 1 of the accidents involved a pedestrian, another accident involved a bicyclist. 5 crashes reported in a complaint of pain injury and 3 resulted in other visible injuries.

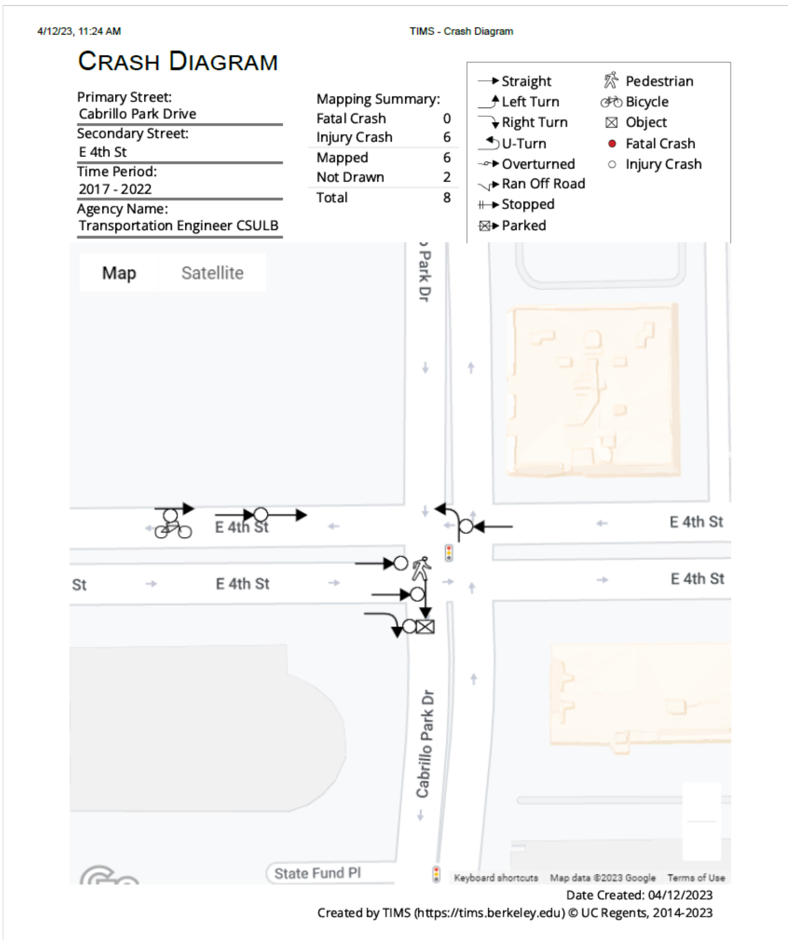
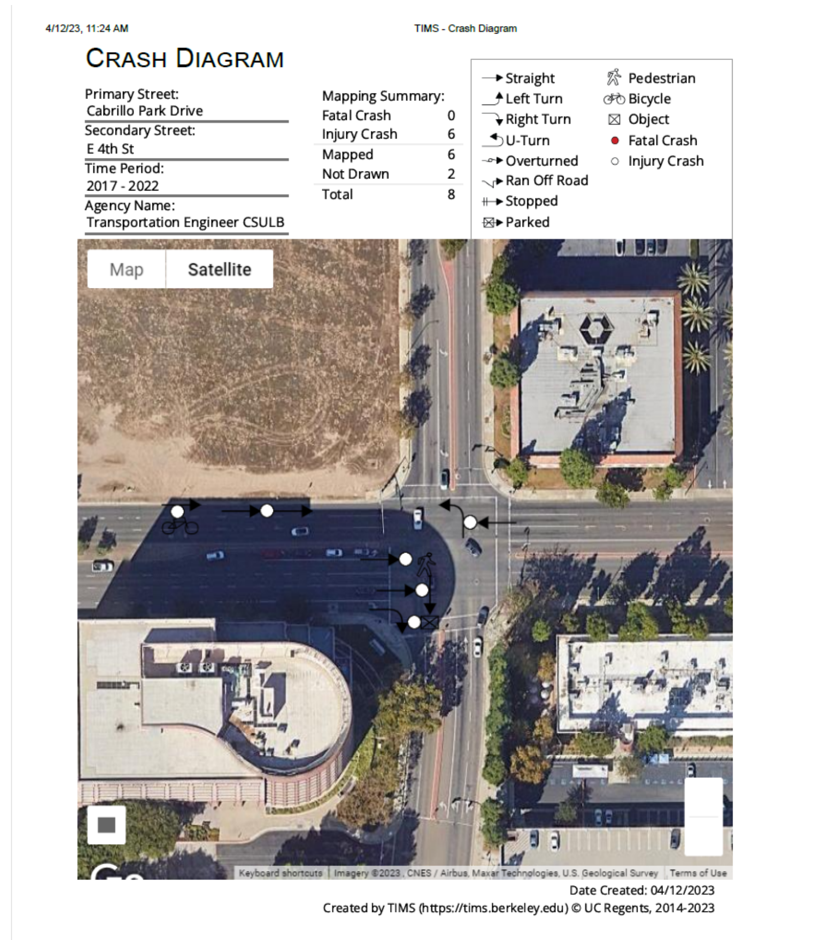


Type of Crash	Count	%
A - Head-On	1	12.50%
C - Rear End	2	25.00%
D - Broadside	2	25.00%
E - Hit Object	1	12.50%
G - Vehicle/Pedestrian	1	12.50%
H - Other	1	12.50%

Figure 198: Number of Crashes by Crash Type - Cabrillo Park Drive & E 4th Street

Collision Diagrams

Table 134: TIMS Collision Diagrams - Cabrillo Park Drive & E 4th Street

Map View	Satellite View
	

Mabury Street & E Fruit Street

Crash Summary

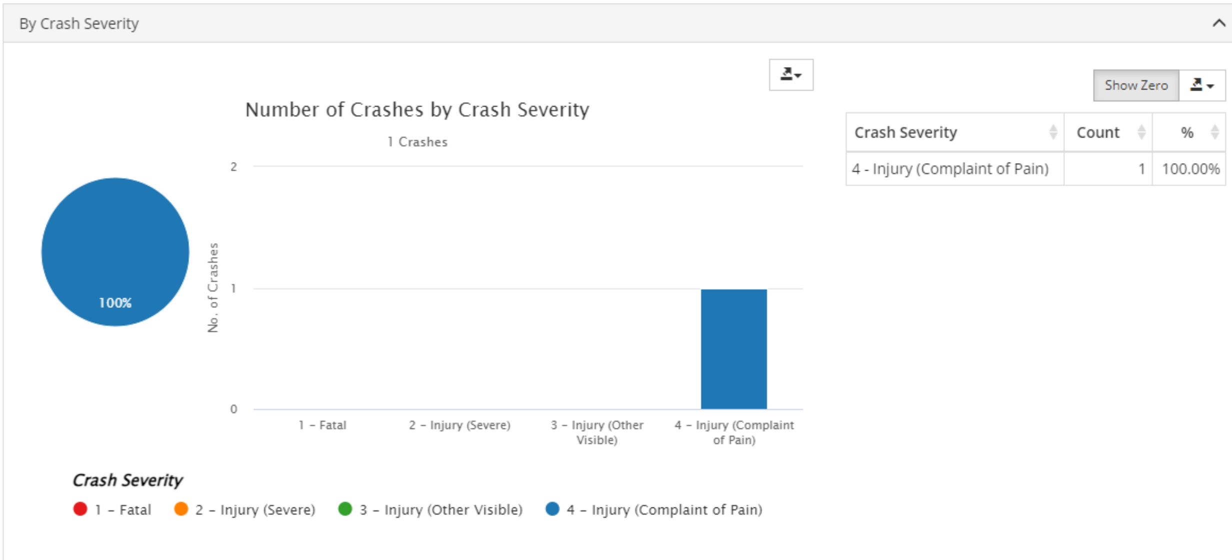


Figure 199: Number of Crashes by Crash Severity - Mabury Street & E Fruit Street

There was only 1 reported crash that resulted in injury at this intersection between 2017 - 2022.

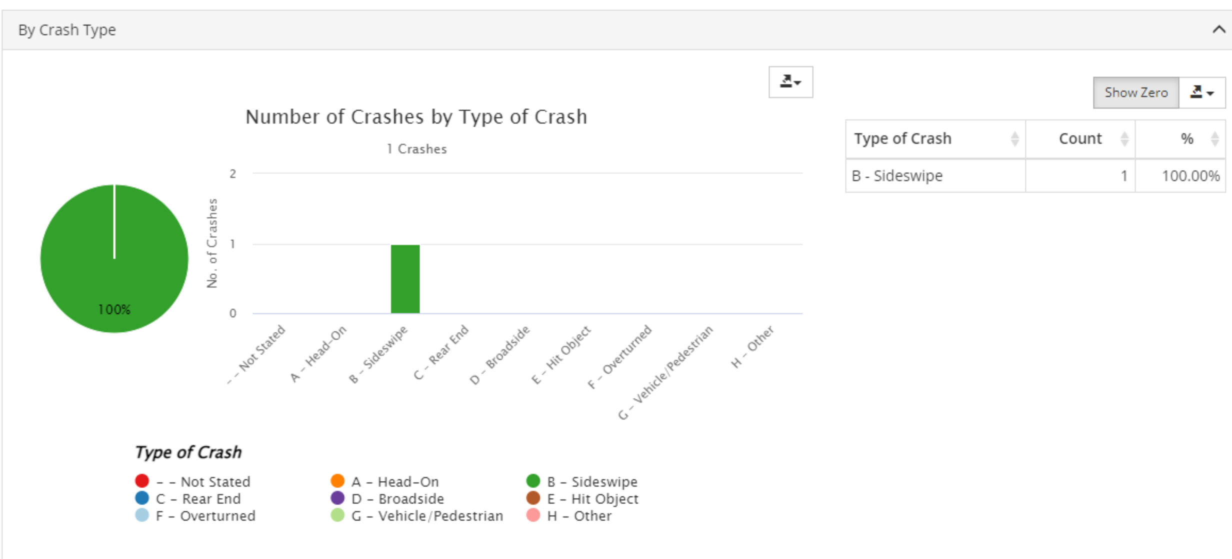
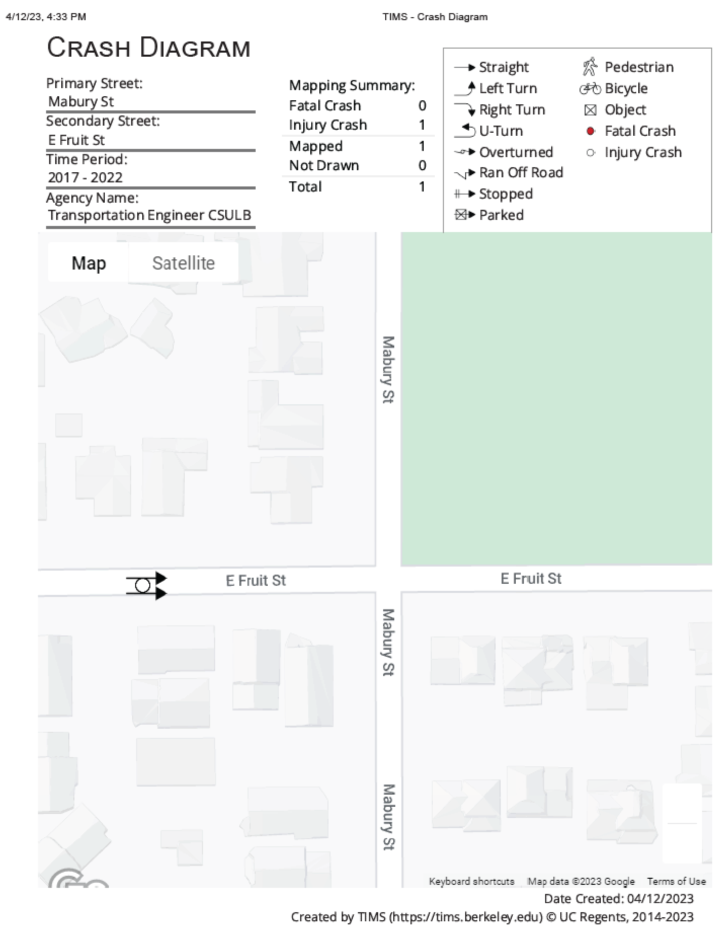


Figure 200: Number of Crashes by Type and Crash - Mabury Street & E Fruit Street

The single accident was the result of a sideswipe.

Collision Diagrams

Table 135: TIMS Collision Diagrams - Mabury Street & E Fruit Street

<table>
<tr><th>Map View</th><th>Satellite View</th></tr>
<tr><td>


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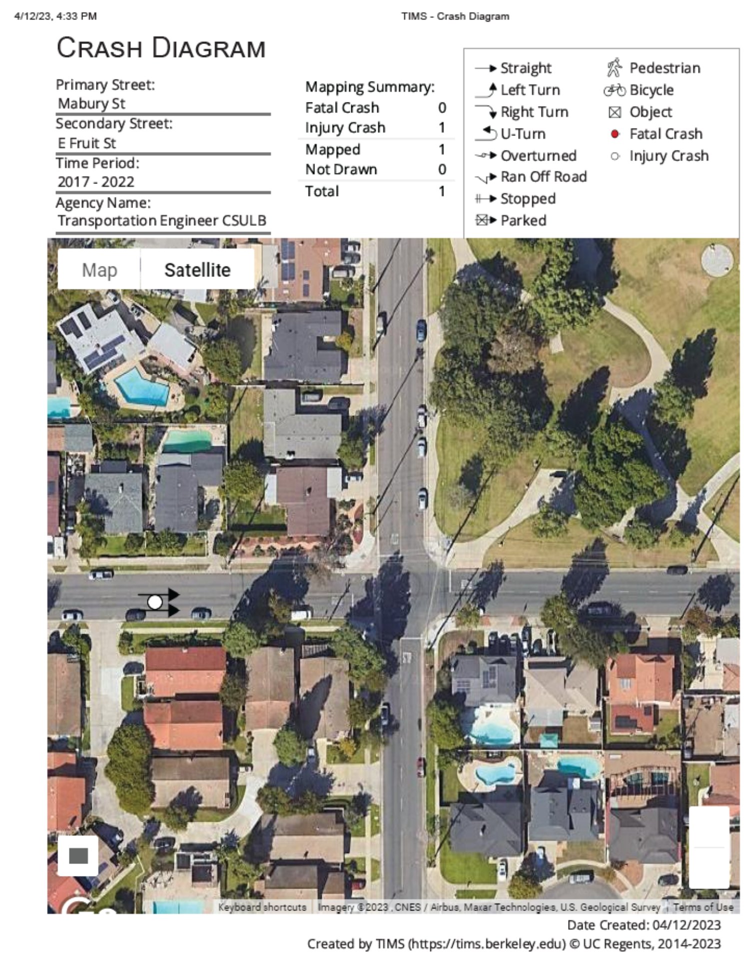

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City of Santa Ana

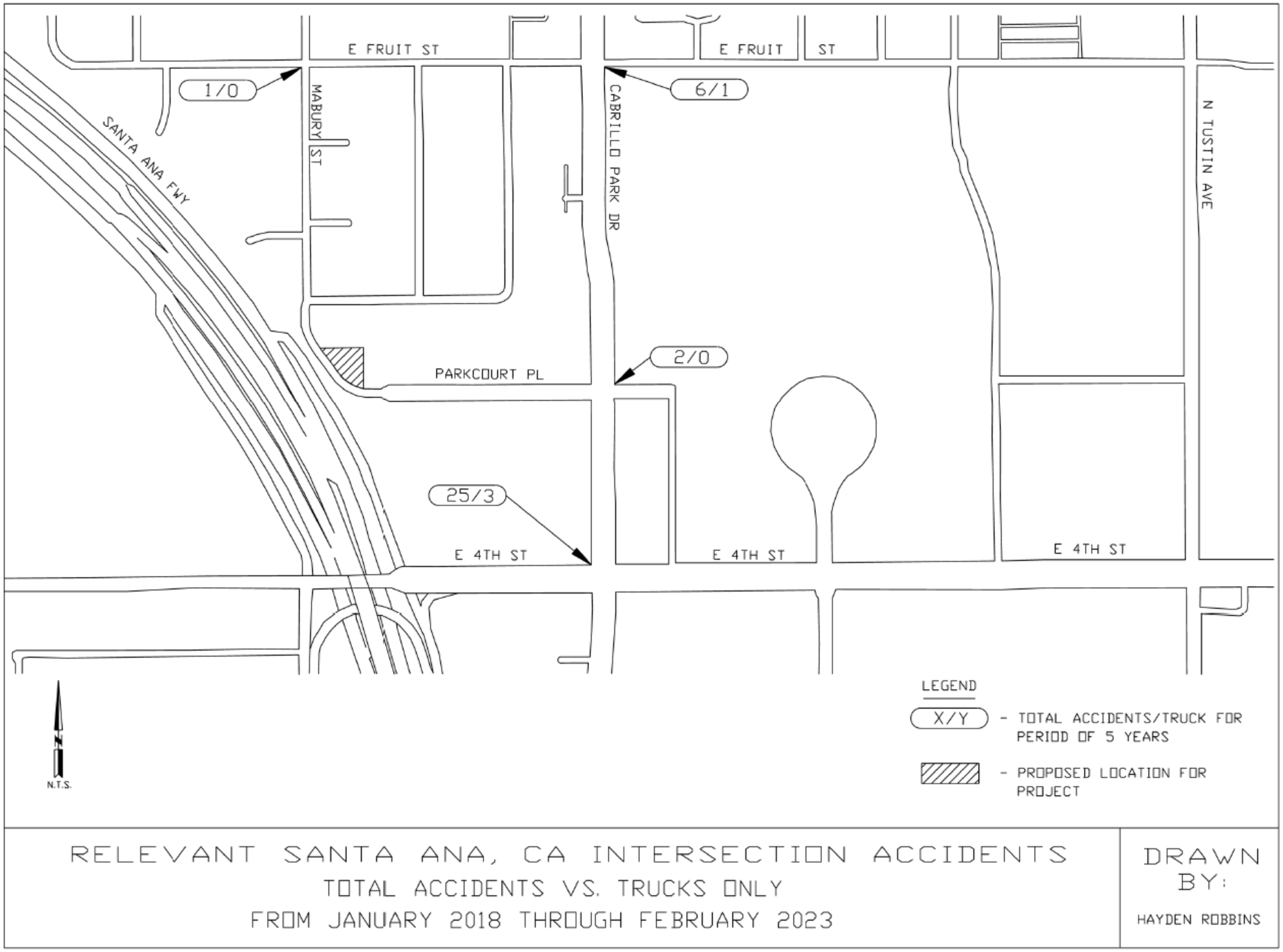

Figure 201: Total Accidents Vs. Truck Accidents - City of Santa Ana

Cabrillo Park Drive and Parkcourt Place. From the City of Santa Ana's Collision Summary Report and the drafted drawing above, there were 2 accidents that occurred at the intersection where the proposed project is located. The first accident involved 3 parties where 2 drivers hit a vehicle that was stopped in the road heading South on Cabrillo Park Drive; only 1 injury was reported. The second accident involved 2 drivers heading North on Cabrillo Park Drive that resulted in a rear-end. Both accidents occurred over a year apart making this intersection relatively safe compared to other surrounding intersections.

Cabrillo Park Drive and 4th Street. Cabrillo Park Drive & 4th St had the highest frequency of accidents, with 28 collisions from the last 5 years. Out of those collisions, 11 were broadsides, 1 was head-on, 3 were with hit objects, 7 were rear-ends and 6 were sideswipes. This intersection is the only intersection that has existing traffic signal controllers. 11 accidents were from the result of "Traffic Signals & Signs," 7 were from Unsafe Speed, another 7 were from Improper Turning, 2 were from Unknown and 1 was from Driving Under the Influence. The most reported cause of accident was: Traffic Signals & Signs (11), Out of 28 collisions, 19 reported injuries.

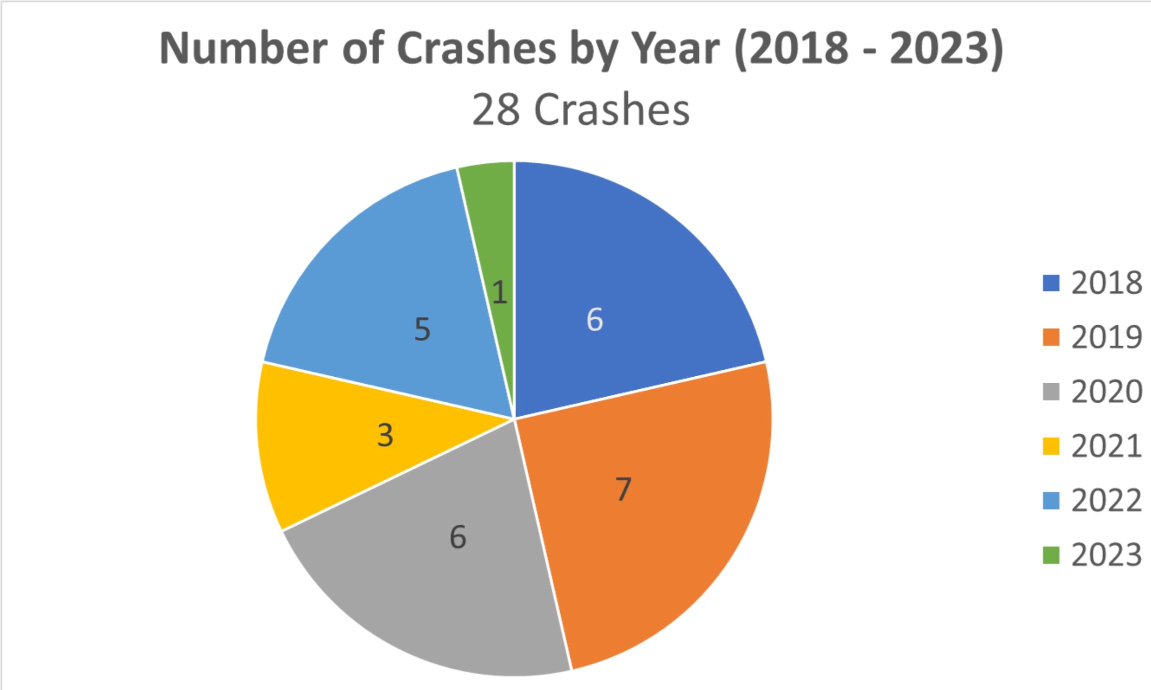

Figure 202: Number of Crashes by Year - Cabrillo Park Drive & 4th Street

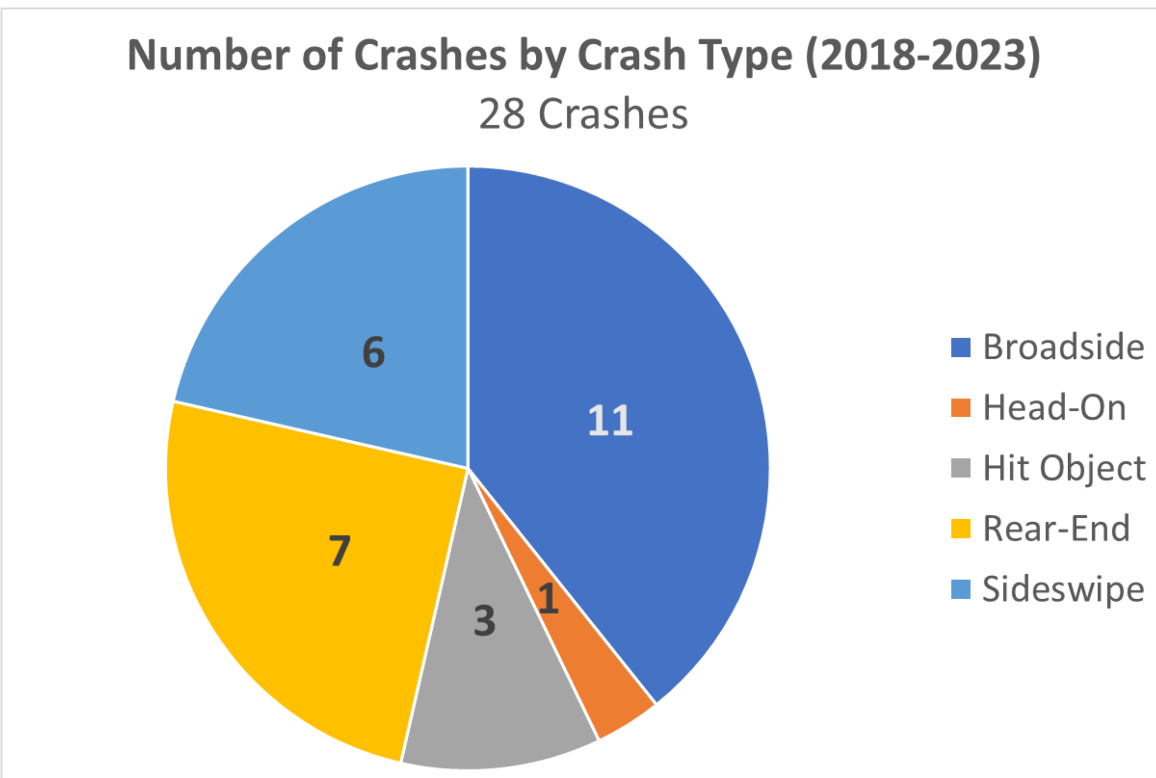

Figure 203: Number of Crashes by Crash Type - Cabrillo Park Drive & 4th Street

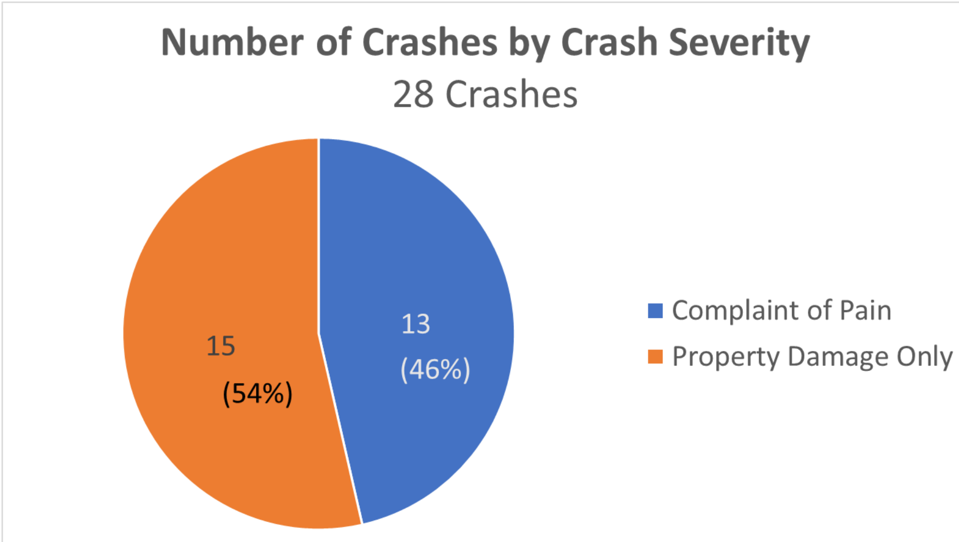

Figure 204: Number of Crashes by Crash Severity - Cabrillo Park Drive & 4th Street

Cabrillo Park Drive & Fruit Street. Cabrillo Park Drive & E Fruit St currently has an all way stop on four approaches. There were 7 reported accidents over the last 5 years, 4 resulting in injury. 5 were broadside, 1 was a hit object and 1 was rear-end.

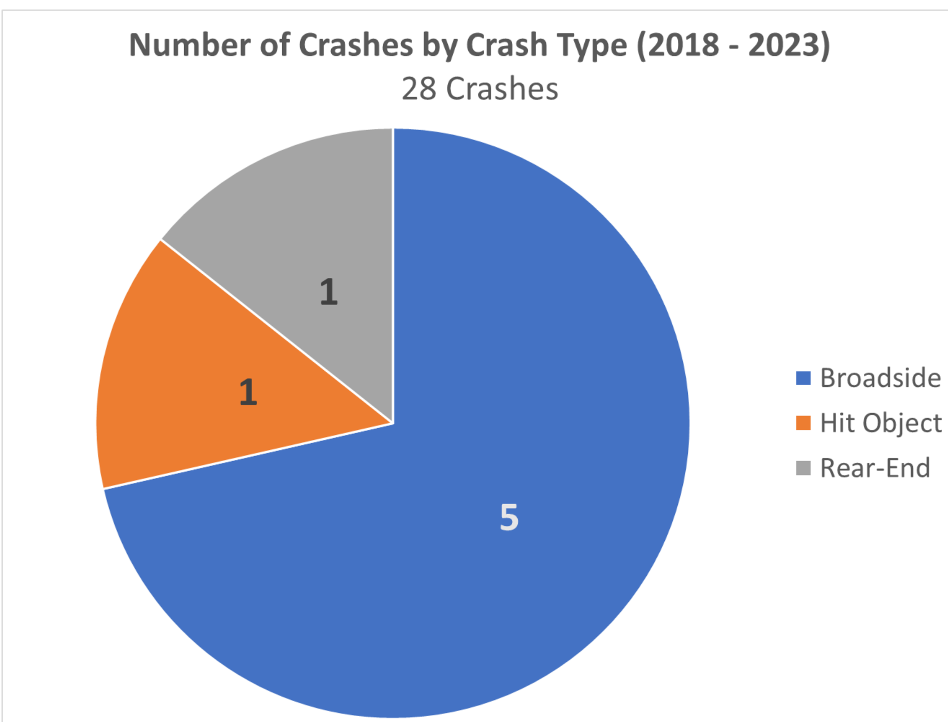

Figure 205: Number of Crashes by Crash Type - Cabrillo Park Drive & Fruit Street

Mabury Street & Fruit Street. There was only 1 collision on Mabury St & Fruit St in 2019, for the last 5 years. This incident involved a passenger car and a bicyclist; no injuries were reported.

TIMs Data Vs. City of Santa Ana Data - 5 Year Study

Table 136: Comparison of TIMs Data & City of Santa Ana Data

Main Street	Minor Street	Reported Crashes	
		TIMs	**Santa Ana**
Cabrillo Park Drive	Parkcourt Place	1	2
	E Fruit Street	6	7
	E 4th Street	8	28
Mabury Street	Fruit Street	1 (Year 2017)	1 (Year 2019)
Total Crashes		16	37

As shown in the Table above, there are 21 crashes that are not accounted for using the TIMs database. Because of this, we used the data from the city of Santa Ana for all design and calculation purposes.

Level of Service (LOS)

Using the criteria from the Highway Capacity Manual 10 (Caltrans, 22):

Table 2. Level of Service Criteria for Unsignalized Intersections

Level of Service	Average Control Delay (seconds/vehicle)
A	0 – 10
B	>10 – 15
C	>15 – 25
D	>25 – 35
E	>35 – 50
F[1]	>50

Figure 206: LOS Criteria for Unsignalized Intersections

The average control delay of a lane is calculated in HCM 6 Equation 2-17

$$d = \frac{3600}{c} + 900T\left[x - 1 + \sqrt{(x - 1)^2 + \frac{\left(\frac{3600}{c}\right)x}{450T}}\right] + 5 \times min[x, 1]$$

Where:

d = average control delay (s/veh)

x = volume-to-capacity ratio of the subject lane

c = capacity of the subject lane (veh/hr)

T = time period (h) (T = 0.25 for a 15-min analysis)

The delay is calculated for each lane on each approach (the results are shown in the Synchro analysis below).

The entry lane flow rate is converted back to vehicles per hour with HCM 6, Equation 22-13:

$$v_i = v_{i,PCE} f_{HV,e}$$

Where:

$v_{i,PCE}$ = demand flow rate for lane i (pc/hr)

v_i = demand flow rate for lane i (veh/hr)

$f_{HV,e}$ = heavy vehicle adjustment factor

The capacity of a lane is converted back to vehicles per hour in Equation 22-14:

$$c_i = c_{i,PCE} f_{HV,e} f_{ped}$$

Where:

$c_{i,PCE}$ = demand flow rate for movement (Epc/hr)

c_i = demand flow rate for movement (veh/hr)

$f_{HV,e}$ = heavy vehicle adjustment factor

f_{ped} = pedestrian adjustment factor

After the delay of each lane is found, the average control delay for the intersection is founding using HCM 6 Equation 22-19:

$$d_{intersection} = \frac{\Sigma d_i v_i}{\Sigma v_i}$$

Where

$d_{intersection}$= average control delay for entire intersection (s/veh)

d_i = control delay for approach i (s/veh)

v_i = flow rate for for approach i (veh/h)

Synchro Analysis

Synchro Software is a traffic signal timing software that assists transportation and traffic engineers design, model, optimize, and analyze signalized and unsignalized intersections. Synchro software was used for our project to analyze a signalized and unsignalized intersection to determine the Level of Service (LOS) to determine how each intersection is performing. We also used the software to obtain a Time-Space Diagram.

Cabrillo Park Drive (North and South) and 4th Street Analysis (West and East)

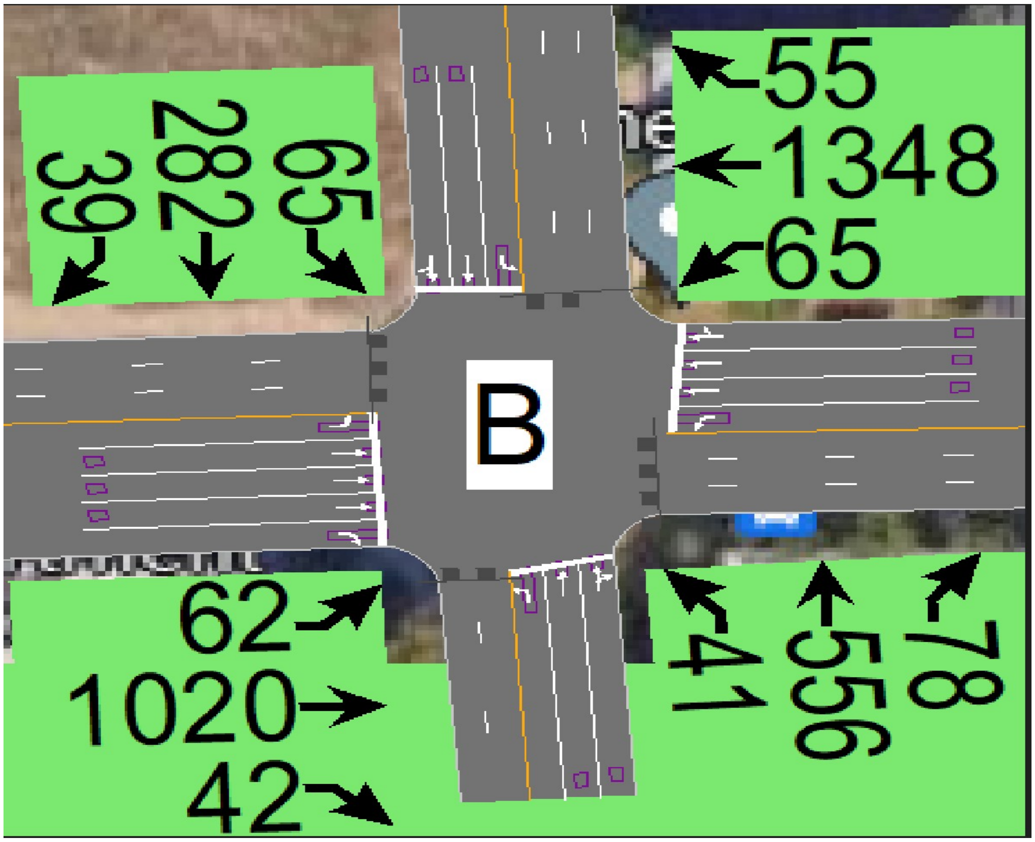

Figure 207: Turning Movement Counts for Cabrillo Park Dr & 4th Street

The intersection of 4th St and Cabrillo Park Dr is a signalized intersection. Using the traffic data we obtained, the hour starting from 4:15 PM - 5:15 PM was used for the intersection Level of Service (LOS) analysis on 4th St and Cabrillo Park Dr which yields a LOS of B. With a LOS of B it shows that this intersection is functioning with steady traffic flow and minimum vehicle delay. The following steps were taken to conduct a signalized intersection Level of Service analysis on Synchro 11:

- Opened Synchro software and started to create a street network with intersections
- Intersections were created by creating links and connecting them together to form intersection

- Once the network is created with the intersections, the lanes for Northbound, Southbound, Eastbound, and Westbound for each intersection was created and this was done by right-clicking on the intersection node and selecting lane settings from the drop down menu in which then I added all lanes that corresponded to the intersection.
- Another configuration that was made was in the time settings in which we specified whether a protected or permitted left turn existed in each direction of the intersection. One important thing to note is that the control type of this signalized intersection was left at pretimed since we weren't able to collect the data needed for the timing of each phase so the default values were used
- The next step was then to add the turning movement counts for each direction and this was done by right clicking on the intersection and clicking on volume settings and once the volume menu opened, we proceeded to insert the turning movement counts from the PM peak hour for this intersection
- Once turning movement volume was imputed and all settings were configured , we were able to obtain the Level of Service for the intersection using the High Capacity Manual (2010) as a reference. This was done by selecting the intersection and then clicking on the LOS button in the HCM 2010 menu that is displayed on Synchro
- A print out of the report was then done by selecting the report menu and selecting the intersection of 4th Street and Cabrillo Park Drive, then clicking on HCM 2010 summary with the signalized option checked. The following report is the report that was generated using the procedure listed above

HCM 2010 Signalized Intersection Summary
19: 4th St & Cabrillo Park Dr 04/19/2023

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	62	1020	42	65	1348	55	41	556	78	65	282	39
Future Volume (veh/h)	62	1020	42	65	1348	55	41	556	78	65	282	39
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1863	1863	1863	1863	1863	1900	1863	1863	1900	1863	1863	1900
Adj Flow Rate, veh/h	67	1109	46	71	1465	60	45	604	85	71	307	42
Adj No. of Lanes	1	3	1	1	3	0	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	212	2034	633	273	2005	82	503	1247	175	352	1253	170
Arrive On Green	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Sat Flow, veh/h	340	5085	1583	485	5011	205	1028	3117	438	751	3133	425
Grp Volume(v), veh/h	67	1109	46	71	991	534	45	342	347	71	172	177
Grp Sat Flow(s),veh/h/ln	340	1695	1583	485	1695	1827	1028	1770	1785	751	1770	1788
Q Serve(g_s), s	6.8	7.5	0.8	5.9	11.2	11.2	1.4	6.5	6.5	3.5	2.9	3.0
Cycle Q Clear(g_c), s	18.0	7.5	0.8	13.5	11.2	11.2	4.3	6.5	6.5	10.0	2.9	3.0
Prop In Lane	1.00		1.00	1.00		0.11	1.00		0.25	1.00		0.24
Lane Grp Cap(c), veh/h	212	2034	633	273	1356	731	503	708	714	352	708	715
V/C Ratio(X)	0.32	0.55	0.07	0.26	0.73	0.73	0.09	0.48	0.49	0.20	0.24	0.25
Avail Cap(c_a), veh/h	212	2034	633	273	1356	731	503	708	714	352	708	715
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	19.9	10.4	8.3	15.5	11.4	11.4	10.4	10.0	10.1	13.8	9.0	9.0
Incr Delay (d2), s/veh	3.9	1.1	0.2	2.3	3.5	6.4	0.4	2.4	2.4	1.3	0.8	0.8
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.0	3.7	0.4	1.0	5.8	6.8	0.4	3.6	3.6	0.9	1.5	1.6
LnGrp Delay(d),s/veh	23.7	11.4	8.6	17.8	14.9	17.8	10.8	12.4	12.4	15.1	9.8	9.8
LnGrp LOS	C	B	A	B	B	B	B	B	B	B	A	A
Approach Vol, veh/h		1222			1596			734			420	
Approach Delay, s/veh		12.0			16.0			12.3			10.7	
Approach LOS		B			B			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		22.5		22.5		22.5		22.5
Change Period (Y+Rc), s		4.5		4.5		4.5		4.5
Max Green Setting (Gmax), s		18.0		18.0		18.0		18.0
Max Q Clear Time (g_c+I1), s		8.5		20.0		12.0		15.5
Green Ext Time (p_c), s		3.1		0.0		1.3		2.1

Intersection Summary	
HCM 2010 Ctrl Delay	13.5
HCM 2010 LOS	B

Figure 208: Synchro Analysis for Signalized Intersection: 4th St & Cabrillo Park Dr

Cabrillo Park Drive (North and South) and Parkcourt Place (West and East)

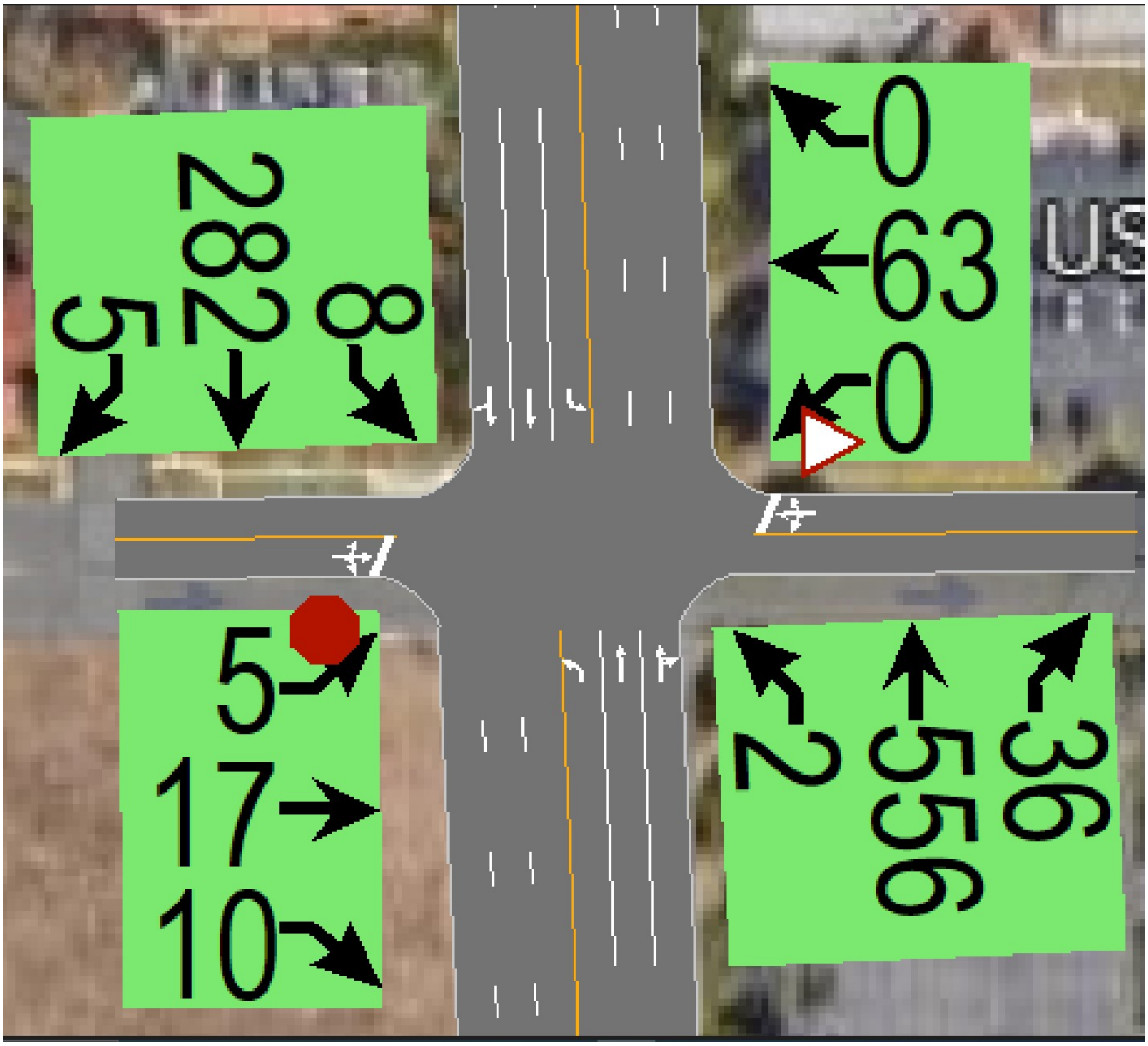

Figure 209: Turning Movement Counts Cabrillo Park Dr and Parkcourt Pl

The intersection of Parkcourt Pl and Cabrillo Park Dr is an unsignalized intersection in which all Northbound and Southbound through lanes are free flowing and the Eastbound direction contains one lane with a stop sign and the Westbound also has one lane but drivers must yield as no stop sign exists there. The PM peak hour of this intersection was from 4:45 PM to 5:45 PM in which the turning counts for that hour were used in our Synchro analysis. Since this intersection is unsignalized and the Northbound and Southbound lanes are free flowing, vehicle delay is at a minimum and possibly negligible. Given this information, this intersection Level of

Service is at an A. The procedure to perform the Synchro analysis on the unsignalized intersection is a little different compared to the signalized intersection of 4th St and Cabrillo Park Dr. The following is the procedure that was followed in order to do the Synchro analysis on this unsignalized intersection.

- With the street network that was already created including the intersections, we proceeded to configure the lane settings in order to have the correct amount of lanes in that intersection
- The Synchro software by default assumes that any intersection that you create is a signalized intersection so in order to change it to a unsignalized intersection we had to select the intersection of Parkcourt Pl and Cabrillo Park Dr and go into the intersection settings, then configure the control type setting by changing it from pre timed to unsignalized
- When an intersection is changed to unsignalized, Synchro by default adds stop signs to all legs of the intersection and to change this we had to configure the intersection settings by selecting our intersection and right-clicking and selecting the timing settings. In the timing settings the sign control option can be configured and from there we added the free flow lanes going Northbound and Southbound , also the Eastbound lane stayed as a stop sign and the Westbound direction was changed to a yield.
- Once the intersection was configured correctly, the volumes were added in the volume settings
- The report is then ready to generate once the previous steps were completed. When generating this report for the unsignalized intersection the report uses the 2000 Highway

Capacity Manual as no changes have been made to the analysis of an unsignalized intersection since then. The following report is the intersection analysis

HCM Unsignalized Intersection Capacity Analysis
20: Parkcourt Pl & Cabrillo Park Dr — 04/19/2023

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	5	17	10	0	63	0	2	556	36	8	282	5
Future Volume (Veh/h)	5	17	10	0	63	0	2	556	36	8	282	5
Sign Control		Stop			Yield			Free			Free	
Grade		0%			0%			0%			0%	
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Hourly flow rate (vph)	5	18	11	0	68	0	2	604	39	9	307	5
Pedestrians												
Lane Width (ft)												
Walking Speed (ft/s)												
Percent Blockage												
Right turn flare (veh)												
Median type								None			None	
Median storage veh)												
Upstream signal (ft)								493				
pX, platoon unblocked	0.94	0.94		0.94	0.94	0.94				0.94		
vC, conflicting volume	668	974	156	819	958	322	312			643		
vC1, stage 1 conf vol												
vC2, stage 2 conf vol												
vCu, unblocked vol	520	846	156	681	828	152	312			494		
tC, single (s)	7.5	6.5	6.9	7.5	6.5	6.9	4.1			4.1		
tC, 2 stage (s)												
tF (s)	3.5	4.0	3.3	3.5	4.0	3.3	2.2			2.2		
p0 queue free %	99	93	99	100	76	100	100			99		
cM capacity (veh/h)	334	277	862	295	284	816	1245			1003		

Direction, Lane #	EB 1	WB 1	NB 1	NB 2	NB 3	SB 1	SB 2	SB 3
Volume Total	34	68	2	403	240	9	205	107
Volume Left	5	0	2	0	0	9	0	0
Volume Right	11	0	0	0	39	0	0	5
cSH	367	284	1245	1700	1700	1003	1700	1700
Volume to Capacity	0.09	0.24	0.00	0.24	0.14	0.01	0.12	0.06
Queue Length 95th (ft)	8	23	0	0	0	1	0	0
Control Delay (s)	15.8	21.6	7.9	0.0	0.0	8.6	0.0	0.0
Lane LOS	C	C	A			A		
Approach Delay (s)	15.8	21.6	0.0			0.2		
Approach LOS	C	C						

Intersection Summary			
Average Delay	2.0		
Intersection Capacity Utilization	29.1%	ICU Level of Service	A
Analysis Period (min)	15		

Figure 210: Synchro Analysis for Unsignalized Intersection: Parkcourt Pl & Cabrillo Park Dr

Time-Space Diagram

A Time-Space Diagram is used to visually see how traffic flows from one signalized intersection to another. This diagram plots time in the horizontal axis and the signal timing on the vertical axis. Many lines are plotted in this diagram and when lines show a constant slope the vehicle is speeding and once the line has a slope of zero as it progresses in time, then it signifies a stop of that vehicle on the diagram. The width of the horizontal line represents the delay per that vehicle and the sum of all horizontal lines represents the queue length at that intersection. In our project, traffic analysis was done on one signalized intersection and one unsignalized intersection. The time-space diagram we generated was not ideal since we did not have two intersections that were signalized in our project. We still generated a diagram for two scenarios one being the 50th percentile of flow which is considered the average traffic flow and the other being the 90th percentile which is a heavier traffic flow. The time-space diagram was generated using the synchro software by selecting the intersection and clicking the TSD button which then generates the time-space diagram.

50th Percentile

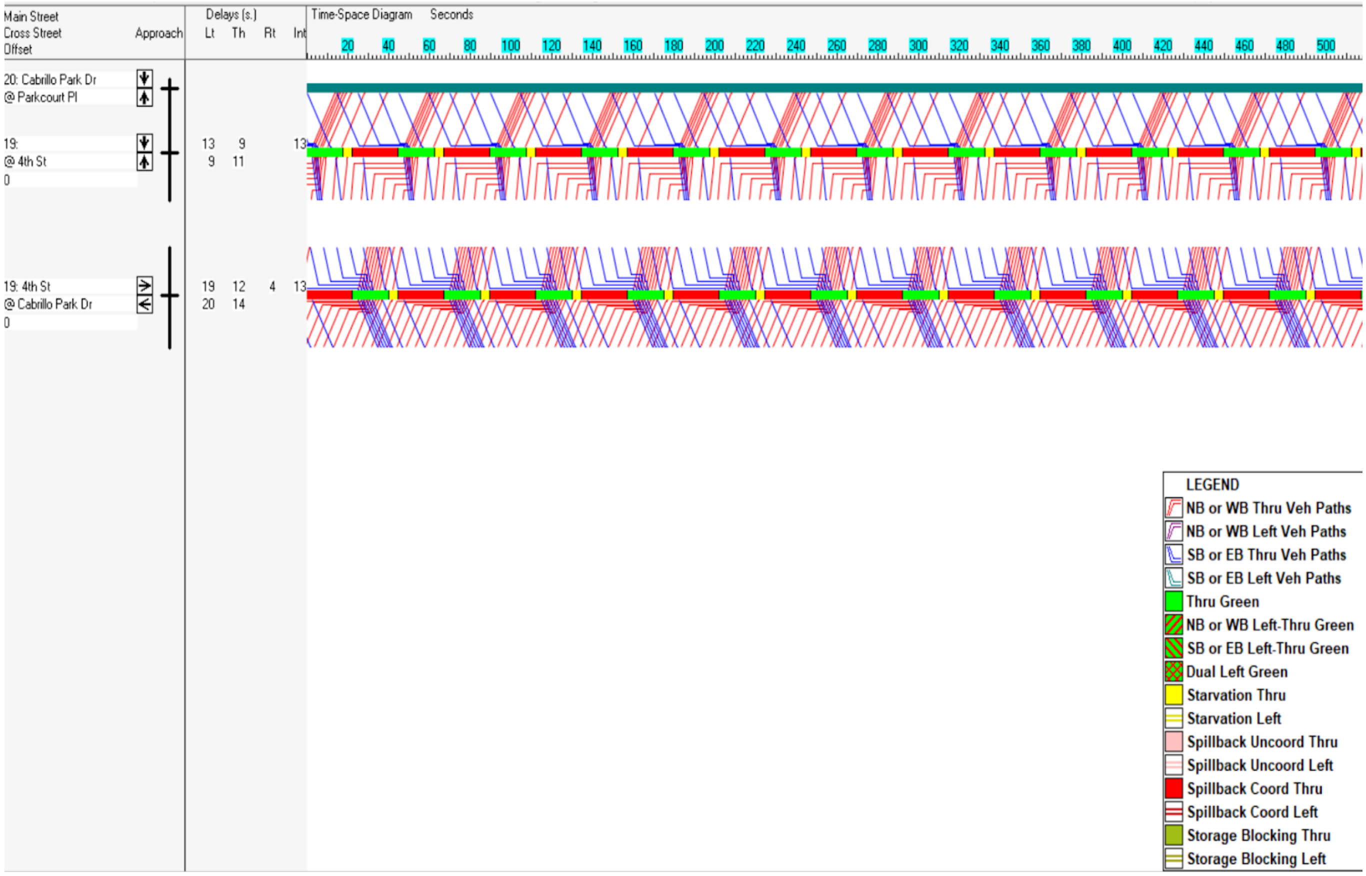

Figure 211: 50th Percentile

This time-space diagram demonstrates the 50th percentile of traffic flow which is the average traffic flow. The red lines show that there is a high queue length and delay going Northbound compared to the Southbound flow which is represented by the blue lines. This diagram also demonstrates how there is no delay or queue on Parkcourt Pl and Cabrillo Park Dr but due to there not being a signal on that intersection thus delay and queue does not develop in that intersection and traffic flow is moving.

90th Percentile

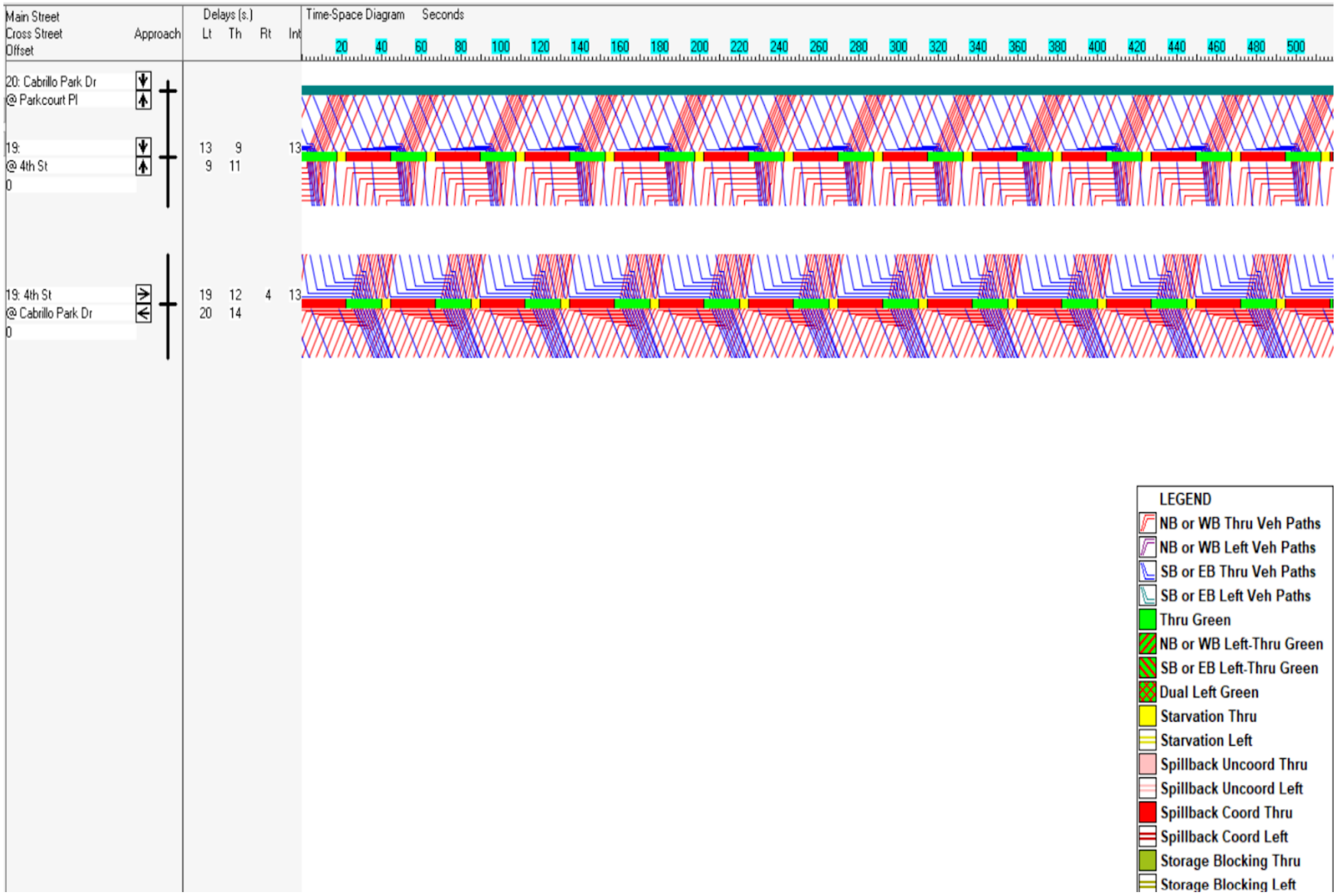

Figure 212: 90th Percentile

When the traffic flow is increased to the 90th percentile, we can observe that queue length and delay dramatically increases with the increase of vehicles.

Proposed Street Improvements

Cabrillo Park Drive and Parkcourt Pl

Most of the proposed transportation improvements focused on the parking lot design (please see section below). Due to the Level of Service being an A and the low accident frequencies, we did not want to implement any striping or signage changes to the intersection.

Cabrillo Park Drive and Fruit Street

Cabrillo Park Drive and E Fruit Street is an all-way stop on all approaches. Based on the crash data received from the City of Santa Ana, there were 7 accidents in the last 5 years, with no more than 2 accidents per year for 2018 and 2022, while 2018, 2020, and 2021 had 1 accident and 2019 did not have a single accident. 4 accidents were the result of auto right-of-way violations and 2 were due to improper turning (1 of them involving a two-axle truck hitting a fixed object). The remaining accident was the result of a driver not paying attention to the stop sign. This data warrants that the existing stop signs are effective at controlling traffic. Possible resolutions may consist of additional driver education on safety, specifically at all-way stop intersections. By analyzing the data, combined with the existing conditions and traffic control studies, this intersection does not need to be improved because it is already an effective and safe intersection.

Cabrillo Park Drive and 4th Street

Insert screenshot with turning guidelines.

As shown in the Existing Conditions section above, this intersection already has Protected-Permissive Left-Turn lanes on the North and South approaches and Protected Left-Turn lanes on the West and East approaches. All approaches have adequate signage and striping according to MUTCD 2014 codes. Another aspect to point out is that all 4 approaches already have channelization medians to improve potential sight distance issues and also provide positive offset. To prevent signage clutter, when there are too many competing signals for a road user to comprehend, we opted for retroreflective pavement markings for the left-turn guidelines on all approaches. According to the FHWA, 57% of drivers consider pavement markings at intersections an important feature (U.S. Department of Transportation - Federal Highway Administration, 2016).

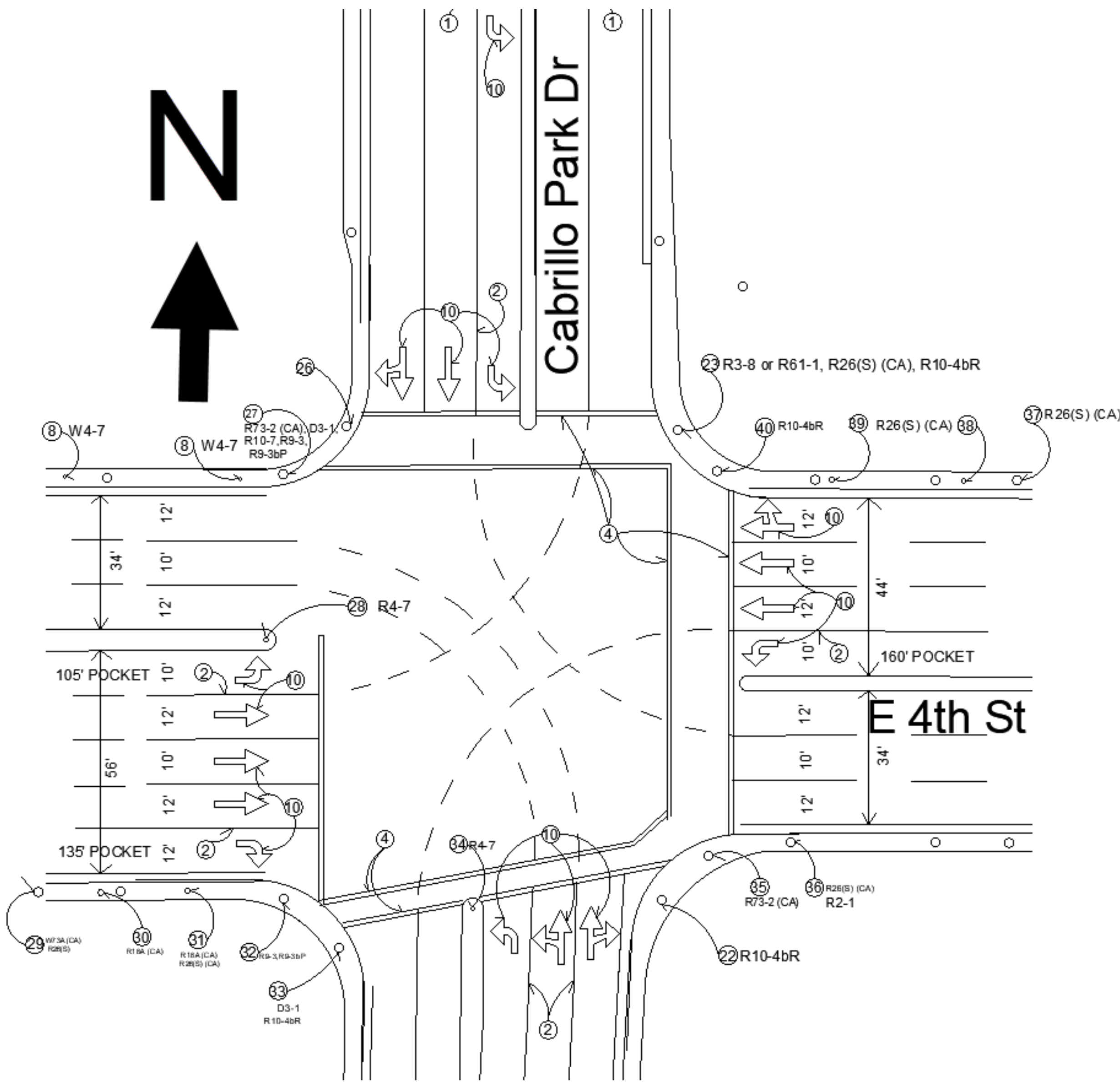

Figure 213: Proposed Street Improvements - Cabrillo Park Drive & E 4th Street

Parking Lot Design

Accessibility

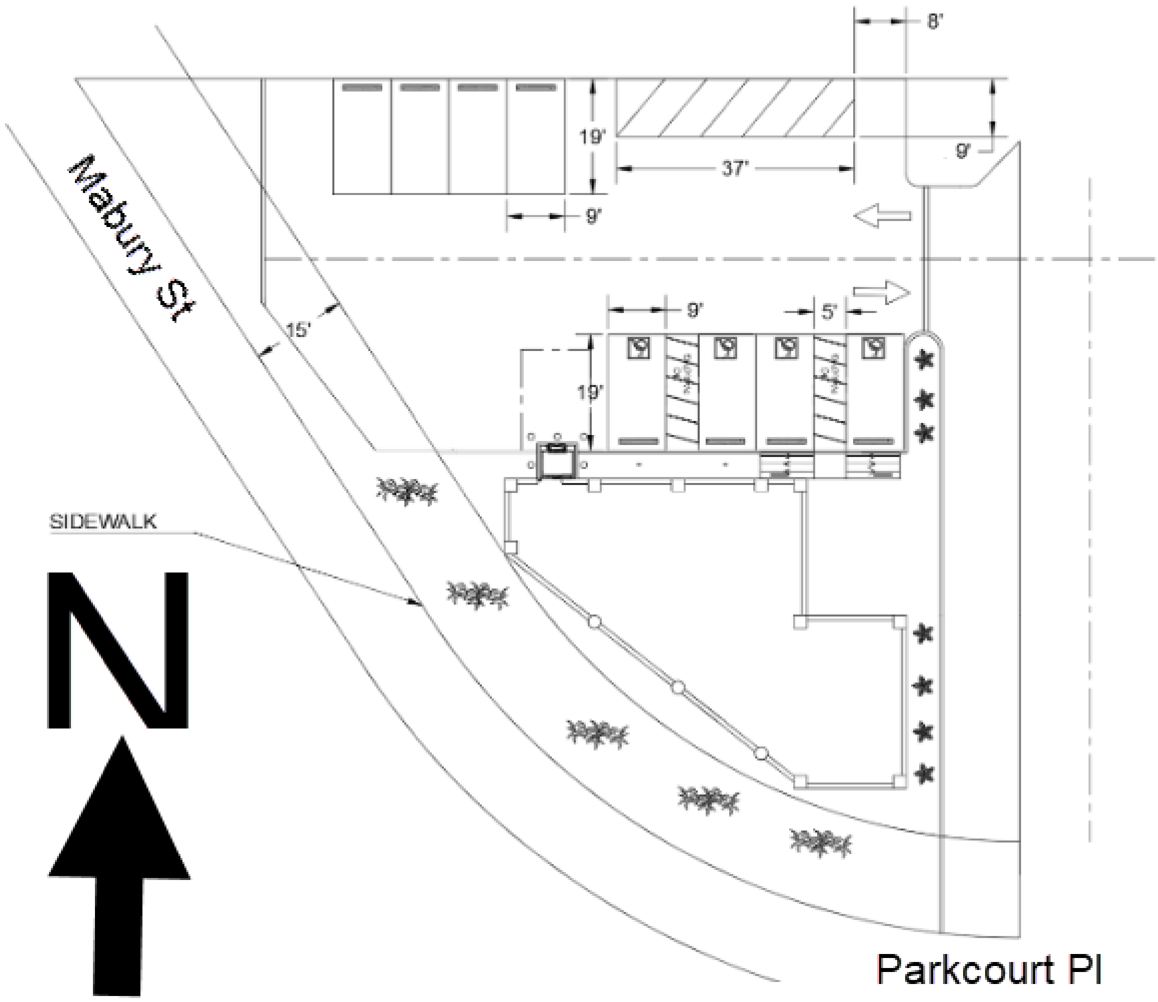

Figure 214: Parking Lot Design

Parking Stalls

Referenced in Relevant Codes below and drawing.

ADA Compliance

Referenced in Relevant Codes below and drawing.