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PROJECT: **LIBRARY STRENGTHENING**

CLIENT: **CITY OF GLENDORA**

SCOPE OF WORK:

RETROFIT OF EXISTING CONCRETE COLUMNS AND NORTH RETAINING WALLS

PROJECT NUMBER: 03025

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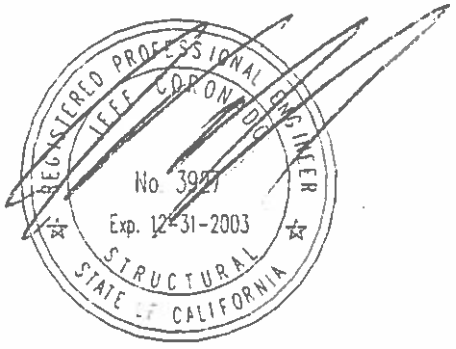
CALCULATIONS 1, 17

JUNE, 2003



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PROJECT: Library Strengthening
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DESIGN OF WALL FRP

1) EXISTING WALL PROPERTIES

$H = 12' = 144"$ $\quad d = 9.8$ in
$t_w = 12"$ $\quad n = 25.78$
$f'_m = 1500$ psi $\quad E_m = 750\, f'_m = 1125$ Ksi
$A_s = \#6@32" = 0.17\ in^2/ft$
$f_y = 40$ Ksi

2) FRP PROPERTIES (SCH 41)

$E = 10900$ Ksi $\quad C_E = 0.85$
$E_D = 0.85 \times 10900 \quad E_G = 9265$ Ksi
$t = 0.04"$
$A_j = 0.5 \times 0.04 \times 12 = 0.24\ in^2/layer$

I- MOMENT CAPACITY WITHOUT COMPOSITES

$M_u = 1.7 \times 3.66 = 6.22$ ft-K
$M_n = 5.42$ ft-K < 6.22 NG

II. CALCULATING STRAINS UNDER EXISTING LOADS

$\rho = \frac{A_s}{bd} = \frac{0.17}{12 \times 9.8} \Rightarrow \rho = 0.00145$ $\quad n = 25.8$

$K = \sqrt{2\rho n + (\rho n)^2} - \rho n = \sqrt{2 \times 0.00145 \times 25.8 + (0.00145 \times 25.8)^2} - 0.00145 \times 25.8$

$K = 0.239$

$J = 1 - \frac{1}{3}K = 1 - \frac{1}{3} \times 0.239 \Rightarrow J = 0.92$

$f_s = \frac{M}{A_s d \left(1 - \frac{K}{3}\right)} = \frac{3.66 \times 12}{0.17 \times 9.8 \times \left(1 - \frac{0.239}{3}\right)} \Rightarrow f_s = 28.64$ Ksi

$\varepsilon_s = \frac{f_s}{E_s} = \frac{28.64}{29000} \Rightarrow \varepsilon_s = 0.00099$

$\varepsilon_i = \frac{h - Kd}{d - Kd} \varepsilon_s = \frac{12 - 0.239 \times 9.8}{9.8 - 0.239 \times 9.8} \times 0.00099 \Rightarrow \varepsilon_i = 0.0028$

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III- ESTIMATE # OF FRP LAYERS

$M_u = M_n + 0.9d \times T_j$

$T_j = \frac{M_u - M_n}{0.9d}$ $\quad A_j F_j = \frac{M_u - M_n}{0.9d} \Rightarrow 0.24 \times (0.002 - 0.00128) \times 9265 n_j = \frac{(6.22 - 5.42) \times 12}{0.9 \times 9.8}$

$t_j = 0.68$ in $\quad$ USE 2 LAYERS OF SCH41

IV CHECK MOMENT CAPACITY AT:

a) LIMIT STATE FOR ULTIMATE COMPRESSIVE STRAIN OF MASONRY

$\varepsilon_m = 0.003$

Assume $c = 1.5"$

$a = 0.85c = 1.275"$

$\varepsilon_t = \frac{h-c}{c}\varepsilon_m = \frac{12-1.5}{1.5} \times 0.003 = 0.021$

$\varepsilon_s = \frac{d-c}{h-c}\varepsilon_t = \frac{9.8-1.5}{12-1.5} \times 0.021 = 0.0166$

$C_m = 0.85 \times 1125 \times 1.275 \times 12 = 14.63$ K

$T_s = 0.17 \times 29000 \times 0.0166 = 81.84$ K $> A_s f_y = 0.17 \times 40 = 6.8$ K

$T_j = (0.021 - 0.00128) \times (2 \times 0.24) \times 9265 = 87.7$ K

$\Sigma F = 0 \quad 87.7 + 6.8 - 14.63 \neq 0$ NG

Try $c = 3.5 \quad a = 2.975$

$C_m = 34.14$ K

$\varepsilon_j = \frac{12-3.5}{3.5} \times 0.003 = 0.0073$

$T_j = (2 \times 0.24) \times (0.0073 - 0.00128) \times 9265 = 26.7$ K

$\varepsilon_s = \frac{d-c}{h-c}\varepsilon_j = \frac{9.8-3.5}{12-3.5} \times 0.0073 = 0.0054$

$T_s = 0.17 \times 29000 \times 0.0054 = 26.62$ K $> A_s f_y = 0.17 \times 40 = 6.8$ K

$\Sigma F = 0 \quad 26.7 + 6.8 - 34.14 = 0.64$ K ≈ 0 OK

$M = 34.14\left(12 - \frac{0.85 \times 3.5}{2}\right) - 6.8 \times (12 - 1.8) \Rightarrow M = 20.60$ ft-K $\gg 6.2$ ft-K

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b) LIMIT STATE FOR MAXIMUM ALLOWABLE STRAIN (0.002)

=2 $\varepsilon_j = \varepsilon_t - \varepsilon_s = 0.002 - 0.00128 = 0.00072$

$T_j = A_j(\varepsilon_t - \varepsilon_s) E_j = (2 \times 0.24) \times 0.00072 \times 9265 = 3.2\ K$

$\varepsilon_s = \frac{d-c}{h-c} \times \varepsilon_t = \frac{9.8-2}{12-2} \times 0.002 = 0.00156$

$T_s = A_s E_s \varepsilon_s = 0.17 \times 29000 \times 0.00156 = 7.69\ K > A_s f_y = 0.17 \times 40 = 6.8\ K$

$\varepsilon_m = \frac{c}{h-c} \times \varepsilon_t = \frac{2}{12-2} \times 0.002 = 0.0004$

$C_m = \frac{1}{2} \varepsilon_m E_m c\, b = \frac{1}{2} \times 0.0004 \times 1125 \times 2 \times 12 = 5.4\ K$

$\Sigma F = 0 \qquad 3.2 + 6.8 - 5.4 \neq 0$

Try $c = 2.64$

$T_j = 3.2\ K$

$\varepsilon_s = 0.00153$

$T_s = 7.55 > 6.8$

$\varepsilon_m = 0.00056$

$C_m = 10.05\ K$

$\Sigma F = 0 \qquad 3.2 + 6.8 - 10.05 = 0.95 \approx 0$ OK

$M = 10.05\left(12 - \frac{2.64}{3}\right) - 6.8\left(12 - 9.8\right)$

$M = 8.07\ ft\text{-}K$

$\phi M_n = 0.8 \times 8.07 = 6.45\ ft\text{-}K$

$\phi M_n = 6.45 > 6.22\ ft\text{-}K\text{-}ips$ OK

USE 2 LAYERS OF TYFO SCH 41 WITH 50% OF THE WALL COVERED

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Checking foundation of walls (North)

Footing 1'-10" x 16" Thickness

f'_c = 2000 psi

f_y = 40 Ksi

$Q = 800\,D + 320\,B$

$Q = 800 \times 2 + 320 \times 1.83 \Rightarrow \quad Q = 2332$ psf

P = 4 Kips (Max) from $P = 2.53$ (Floor) Kips + 1.5 (wall) Kips = 4 Kips

$q = \dfrac{4}{1.83 \times 1} \Rightarrow q = 2.18\ K/ft^2 < 2.33\ K/ft^2$ OK

Footing Adequate

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Columns

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LOADS

D.L.

2½"	Lt wt Concrete topping	= 25 psf
1"	Rigid Insulation	= 1.5 psf
4½"	Structural Concrete Slab	= 54.5 psf
* For 6" waffel slab		= 72.5 psf

D.L = 26.5 + 72.5 = 99 psf (where is the waffel slab)
D.L = 26.5 + 54.5 = 81 psf (structural concrete slab)

L.L. = 100 psf (Non reducible)

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INTERIOR COLUMNS (24" x 96")

DL = 335.4 Kips

LL = 101.3 Kips

f_y = 40 Ksi

f'_c = 3000 psi

-Providing ductility to the column

According to UBC 1921.4.4.1

Adding 4½" to the column

New Interior Column (33" x 105") Clear Cover = 2"

Using :

$$A_{sh} = 0.3 \left(s \times h_c \times \frac{f'_c}{f_{yh}} \right) \left[\frac{A_g}{A_{ch}} - 1 \right]$$

or $$A_{sh} = 0.09 \left(s \times l_c \times \frac{f'_c}{f_{yh}} \right)$$

Solving : Long direction

$$\frac{A_{sh}}{s} = 0.3 \times \left(100.38 \times \frac{3000}{60000} \right) \left[\frac{33 \times 105}{29 \times 101} - 1 \right]$$

$$\frac{A_{sh}}{s} = 0.28 \frac{in^2}{in} \qquad s_{max} = 4" \Rightarrow \qquad A_{sh} = 1.10\ in^2$$

$$\frac{A_{sh}}{s} = 0.09 \left(100.38 \times \frac{3}{60} \right)$$

$$\frac{A_{sh}}{s} = 0.415 \qquad s_{max} = 4" \Rightarrow \qquad A_{sh} = 1.79\ in^2 \rightarrow$$

Use 2 #5 and 6 #4 cross ties

s = 4in

Solving : Short direction

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$$\frac{A_{sh}}{s} = 0.3\left(28.38 \times \frac{3}{60}\right)\left[\frac{33 \times 105}{29 \times 101} - 1\right]$$

$\frac{A_{sh}}{s} = 0.078$ if $s_{max} = 4"$ $\Rightarrow$ $A_{sh} = 0.31\ in^2$

$$\frac{A_{sh}}{s} = 0.09\left(28.38 \times \frac{3}{60}\right)$$

$\frac{A_{sh}}{s} = 0.13$ if $s_{max} = 4"$ $\Rightarrow$ $A_{sh} = 0.51\ in^2$ →

Use 2 #5 and 1 #4 ties
$s = 4in$

Length

L_o = { 1/6 clear span = $\frac{1}{6} \times 10 \times 12 = 20\ in$
18 in
depth of the member = 33" ⇒ Controls

Provide transverse reinforcement with $s = 4"$ at the bottom and top of the column within a length of 33"

Couplers
If needed

Use Barbon - Couplers 5M

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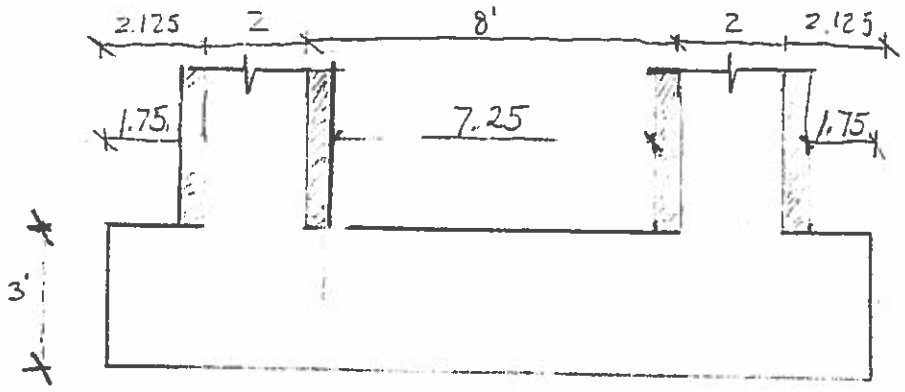
Checking Foundation of Interior Columns

$f'_c = 2000$ psi
$f_y = 40$ Ksi

Footing 13' x 16.25' x 36" Thickness
#10 @ 12" $Q^* = 5000$ psf
DL = 335.4 K
LL = 101.3 K



$Q = 800 \times D + 320 \times D = 800 \times 3 + 320 \times 13 = 6560$ psf > 5000 psf

Use $Q = 5000$ psf

DL + LL = 436.7 K

New DL = $(2 \times 4.5 \times 105 + 2 \times 4.5 \times 24)$

New ... $(945 + 216) = 1161$ in^2 = 8.06 ft^2

New DL = $8.06 \times 10 \times 145 \frac{lb}{ft^3} = 11.69$ K

New total load = 436.7 + 11.69 = 448.4 kips

$f_s = \frac{P}{A} = \frac{448.4}{13' \times 16.25'} = \frac{448.4}{211.25} \Rightarrow f_s = 2.12$ Ksf < 5 Ksf OK

$q_u = \frac{1.4(335.4 + 11.69) + 1.7(101.3)}{13' \times 16.25'} \Rightarrow q_u = \frac{485.93 + 172.21}{211.25}$

$q_u = 3.11$ Ksf

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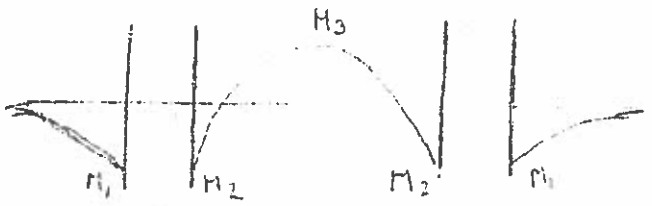

$M_1 = \frac{1}{2} w_u \times L^2 = \frac{1}{2} \times 3.11 \times 1.75^2 = 4.76$

$M_2 = \frac{1}{12} w_u \times L^2 = \frac{1}{12} \times 7.25^2 \times 3.11 = 13.62$ → Controls

$M_3 = \frac{1}{24} w_u \times L^2 = \frac{1}{24} \times 3.11 \times 7.25^2 = 6.81$

Try $a = 2.5$

$$A_{s\ req} = \frac{M_u}{\phi f_y \left(d - \frac{a}{2}\right)} = \frac{13.62 \times 12}{0.9 \times 40 \times \left(32 - \frac{2.5}{2}\right)} = \frac{163.44}{1107}$$

OK

$A_{s\ req} = 0.15\ in^2 < 1.27$ (1 #10)

$$a = \frac{A_s f_y}{0.85 \times f'_c\, b} = \frac{1.27 \times 40}{0.85 \times 2 \times 12} = 2.49 \approx 2.5$$

Column Footing Adequate

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North Columns

Columns 16" x 144"

DL = 137.2 Kips

LL = 55.9 Kips

Providing ductility to the columns

Adding 4½" to the Column

New North and South Columns (25" x 153") Clear Cover = 2"

Solving: Long direction

$$\frac{A_{sh}}{s} = 0.3\left(148.4 \times \frac{3}{60}\right)\times\left[\frac{25\times153}{21\times149} - 1\right]$$

$$\frac{A_{sh}}{s} = 0.44\ \frac{in^2}{in} \quad \text{if } s_{max} = 4in \Rightarrow A_{sh} = 1.98\ in^2$$

$$\frac{A_{sh}}{s} = 0.09\times\left(1484\times\frac{3}{60}\right)$$

$$\frac{A_{sh}}{s} = 0.67\ \frac{in^2}{in} \quad \text{if } s_{max} = 4in \Rightarrow A_{sh} = 2.67\ in^2 \rightarrow$$

Use 2#5 and #5@14" crossties
s = 4in

Solving: Short direction

$$\frac{A_{sh}}{s} = 0.3\left(20.4\times\frac{3}{60}\right)\times\left[\frac{25\times153}{21\times149} - 1\right]$$

$$\frac{A_{sh}}{s} = 0.068\ \frac{in^2}{in} \quad \text{if } s_{max} = 4in \Rightarrow A_{sh} = 0.27\ in^2$$

$$\frac{A_{sh}}{s} = 0.09\left(20.4\times\frac{3}{60}\right) =$$

$$\frac{A_{sh}}{s} = 0.09\ \frac{in^2}{in} \quad \text{if } s_{max} = 4in \Rightarrow A_{sh} = 0.37\ in^2 \rightarrow$$

Use 2#5 and 1#4 crosstie*
s = 4in

* In this case not used

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Length

l_o = { ⅙ clear span = 20 in
18 in
Depth = 25" → Controls

Provide transverse reinforcement with s=4" at top and bottom within a length of 25" in the column

Couplers

If needed

Use Bar-lock couplers 3M

s = 4 in

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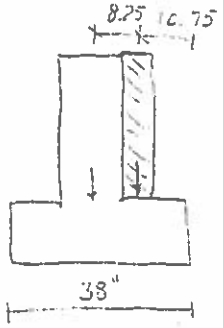
Checking Foundation of North Columns

Footing 3'-2" x 12' x 16" Thickness



DL = 49 k

LL = 21.8 k

f'_c = 2000 psi

f_y = 40 ksi

$Q = 800 \times 2 + 400 \times 3.17 = 2868 \text{ psf} < 5000 \text{ psf}$

$$f_{s_1} = \frac{70.8}{3.17 \times 12} = 1.86 \text{ ksf}$$

$$P = \frac{4.0}{12} \times 12 \times 12 \times 145 \frac{\text{lb}}{\text{ft}^3} = 7.83 \text{ k}$$

$$P_{max} = \frac{2P}{3ab} = \frac{2 \times 7.83}{3 \times \frac{10.75}{12} \times 12}$$

f_{s_2} = 0.48 ksf

$f_s = f_{s_1} + f_{s_2} = 1.86 + 0.48 = 2.35 \text{ ksf} < 2.87 \text{ ksf}$ OK

Footing Adequate

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East and West Columns (16" x 96")

DL = 51.4 k

LL = 22.1 k

f_y = 40 ksi

f'_c = 3000 psi

Providing ductility to the column

Adding 4½" concrete

New West Column (25" x 105") Clear Cover = 2"

Solving: Long direction

$$\frac{A_{sh}}{s} = 0.3 \times \left(100.38 \times \frac{3000}{60000}\right)\left[\frac{25 \times 105}{21 \times 101} - 1\right]$$

$\frac{A_{sh}}{s} = 0.36$ if $s = 4"$ $\Rightarrow$ $A_{sh} = 1.43\ in^2$

$$\frac{A_{sh}}{s} = 0.09 \times \left(100.38 \times \frac{s}{60}\right)$$

$\frac{A_{sh}}{s} = 0.45$ if $s = 4"$ $\Rightarrow$ $A_{sh} = 1.79\ in^2$ $\rightarrow$ Use 2 #5 and 6 #4 crossties

$s = 4in$

Solving: Short direction

$$\frac{A_{sh}}{s} = 0.3 \times \left(20.38 \times \frac{3}{60}\right)\left[\frac{25 \times 105}{21 \times 101} - 1\right]$$

$\frac{A_{sh}}{s} = 0.073 \frac{in^2}{in}$ if $s = 4"$ $\Rightarrow$ $A_{sh} = 0.29\ in^2$

$$\frac{A_{sh}}{s} = 0.09 \left(20.38 \times \frac{3}{60}\right)$$

$\frac{A_{sh}}{s} = 0.092$ if $s = 4"$ $\Rightarrow$ $A_{sh} = 0.37\ in^2$

Use 2 #5 and 1 #4 crossties

$s = 4in$

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Length

L_o = { 1/6 clear span = 20 in
18 in
depth = 25" → Controls

Provide transverse reinforcement with s=4" at bottom and top within a 33" length of the column

Couplers

If needed

Use Barlock. couplers SM

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Checking Foundation for West Columns

Footing 9'4" x 5'6" x 24" thickness

8 #5 at Bottom

f_c = 2000 psi

f_y = 40ksi

DL = 101.4 K

LL = 40.9 K

Q = 800 x 2.5 + 400 x 5.5 = 4200 psf < 5000 psf

$f_{s_1} = \frac{101.4 + 40.9}{5.5 \times 9.33} \Rightarrow f_{s_1} = 2.77$ ksf

$f_{s_2} = \frac{P}{A} = \frac{(25 \times 105 - .16 \times 96) \times 10 \times 145}{5.5 \times 9.33} \Rightarrow f_{s_2} = \frac{10.96}{51.33} \Rightarrow f_{s_2} = 0.22$ ksf

$f_s = f_{s_1} + f_{s_2} = 2.98$ ksf < 4.2 ksf OK

Footing Adequate

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Checking East Column Foundations

Footing 3'6" x 8' x 16" Thickness

f'_c = 2000 psi

f_y = 40 Ksi

DL = 49 Kips

LL = 21.8 Kips

$Q = 800 \times 2 + 400 \times 3.5 = 3000 \text{ psf} < 5000$

$f_{s_1} = \frac{49 + 21.8}{3.5 \times 8} \Rightarrow f_{s_1} = 2.52 \text{ Ksf}$

$f_{s_2} = \frac{(25 \times 105 - 16 \times 96) \times 10 \times 145}{3.5 \times 8} = 0.39 \text{ Ksf}$

$f_s = 2.52 + 0.39 \Rightarrow f_s = 2.91 \text{ ksf} < 3.0 \text{ Ksf}$ OK

Footing Adequate