PRCNC20240061

Gray & Osborne, Inc.
CONSULTING ENGINEERS

STRUCTURAL CALCULATIONS
FOR

City of Puyallup
WPCP Secondary Clarifier No. 3

Prepared by

Gray & Osborne, Inc.

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Seattle, WA 98144

FULL SIZED LEDGIBLE **COLOR** PLANS ARE REQUIRED TO BE PROVIDED BY THE PERMITTEE ON SITE FOR ALL INSPECTIONS **(MIN. PLAN SIZE 24" X 36")**

April 2023

City of Puyallup
Building
ACCEPTED
JMontgomery
02/02/2024
8:44:28 AM

ALEX MW QUINN
STATE OF WASHINGTON
21019150
REGISTERED
PROFESSIONAL ENGINEER
06/14/2023

City of Puyallup
Development & Permitting Services
ISSUED PERMIT

Building	Planning
Engineering	Public Works
Fire	Traffic

PRCNC20240061

Code Versions Used:

International Building Code (IBC 2021)

Building Code Requirements for Structural Concrete (ACI 318-19)

Code Requirements for Environmental Engineering Concrete Structures (ACI 350-20)

Minimum Design Loads and Associated Criteria for Buildings and other Structures (ASCE/SEI 7-22)

Secondary Clarifier No. 3 - Design Inputs

General

Diameter (D) =	110.00	ft	
Radius (R) =	55.00	ft	
f'c =	4000	psi	
fy =	60000	psi	
Steel modulus (E_s) =	2.9E+07	psi	
Conc modulus (E_c) =	3.6E+06	psi	
Water weight (P_w) =	62.40	pcf	
Soil pressure (P_s) =	85.00	pcf	
Fill weight (W_f) =	60.00	pcf	
Fill angle =	60.00	deg	
Conc weight (W_c) =	150.0	pcf	
EQ pressure (E) =	180.0	psf	*From Geotechnical Report*

Wall Parameters

Height (H_w) =	20.00	ft	
Fill height (H_f) =	18.00	ft	
Thickness (t_w) =	16.00	in	
b_w =	12.00	in	
d_w =	13.50	in	*Assume 2" cover*

Slab Parameters

Thickness (t_s) =	18.00	in	
b_s =	12.00	in	
d_s =	14.50	in	*Assume 3" cover*
Footing extension =	1.00	ft	
GWT (from b.o.f.) =	5.50	ft	*(PRV 2'-0" above footing)*

Wall Design Case 1 - Tank Full, No Backfill

Tank Properties

H_w =	20.00	ft	f'c =	4000	psi
t_w =	16.00	in	fy =	60000	psi
b_w =	12.00	in	$f_{s,max}$,hoop =	17000	psi
d_w =	13.50	in	$f_{s,max}$,shear =	20000	psi
P_w =	62.40	psf	$f_{s,max}$,flexure =	17000	psi
D =	110.00	ft	E_s =	2.9E+07	psi
R =	55.00	ft	E_c =	3604997	psi
H^2/Dt_w =	2.73	ft	$n = E_s/E_c$ =	8.04	
Water pressure (q) =	1248	psf			
U_F =	1.60		*Lateral liquid pressure load factor (ACI 350)*		
U_H =	1.40		*Soil pressure load factor (ACI 318)*		

Tension - Horizontal Steel

T= CqR

C =	0.519			*"Circular Concrete Tanks" Table A5*
T =	35.62	kip		*Unfactored force*
T_u =	57.00	kip		*Factored tension force*
γ =	1.60			*Factored/unfactored load ratio*
S_d =	1.99			*Environmental durability factor*
S_dT_u =	113.16	kip		*Required hoop tension strength*
2 layers A_s,req'd =	2.096	in^2		
#7 Bar Area =	0.600	in^2 @ s =	6.00	in o.c.
A_s,provided =	2.400	in^2	OK	

Max Tensile Stress

f'c =	267	<	400	Crack Control OK

Moment - Vertical Steel

$M=CqH^2$

C =	0.0219			*"Circular Concrete Tanks" Table A7*
M =	10.93	kip*in		*Unfactored moment*
M_u =	17.49	kip*in		*Factored moment*
γ =	1.60			*Factored/unfactored load ratio*
S_d =	1.99			*Environmental durability factor*
$S_dM_u/(\Phi f'cb_wd_w^2)$ =	0.0529		0.050	0.003
ω =	0.0513			*"Circular Concrete Tanks" Table A20*
ρ =	0.0034	<	0.0033	
A_s,req'd =	0.554	in^2		
#7 Bar Area =	0.600	in^2 @ s =	10.00	in
A_s,provided =	0.720	in^2	OK	

Shear

$\Phi V_c=\Phi 2sqrt(f'c)b_wd_w$ =	15.37	kip		*Concrete shear capacity*
C =	0.189			*"Circular Concrete Tanks" Table A12*
V_u =	7.55	kip	OK	*Factored shear force*

Wall Design Case 2 - Tank Empty, Full Backfill

Tank Properties

H_w =	18.00	ft	f'c =	4000	psi
t_w =	16.00	in	fy =	60000	psi
b_w =	12.00	in	$f_{s,max}$,hoop =	17000	psi
d_w =	13.50	in	$f_{s,max}$,shear =	20000	psi
P_s =	85.00	pcf	$f_{s,max}$,flexure =	17000	psi
E =	180	psf	E_s =	2.9E+07	psi
D =	110.00	ft	E_c =	3604997	psi
R =	55.00	ft	$n = E_s/E_c$ =	8.04	
H^2/Dt_w =	2.21	ft			
Soil pressure (q) =	1530	psf			
U_F =	1.60		*Lateral liquid pressure load factor (ACI 350)*		
U_E =	1.40		*Soil pressure load factor (ACI 318)*		

Compression

C_L =	0.519	(linear)		*"Circular Concrete Tanks" Table A5&A6*
C_U =	1.205	(unifrom)		
$P = C_LqR+C_UER$	55.6	kip		*Unfactored force*
P_u =	77.8	kip		*Factored compression force*
ΦP_n =	339.5	kip		*Concrete compression capacity*
Pn > Pu	OK			

Moment - Vertical Steel

C_L =	0.0219	(linear)			*"Circular Concrete Tanks" Table A7*
C_U =	0.0219	(uniform)			
$M = C_LqH^2+C_UEH^2$	12.13	kip*ft			*Unfactored moment*
M_u =	16.99	kip*ft			*Factored moment*
γ =	1.40				*Factored/unfactored load ratio*
S_d =	2.27				*Environmental durability factor*
$S_dM_u/(\Phi f'cb_wd_w^2)$ =	0.05874		0.050	0.009	
ω =	0.0569				*"Circular Concrete Tanks" Table A20*
ρ = ω(f'c/fy)	0.00379	<	0.0033		
A_s,req'd= ρb_wd_w	0.615	in^2			
#7 Bar Area =	0.600	in^2 @ s =	10.00	in	
A_s,provided =	0.720	in^2	OK		

Shear

$\Phi V_c = \Phi 2\text{sqrt}(f'c)b_wd_w$=	15.4	kip		*Concrete shear capacity*
C =	0.189			*"Circular Concrete Tanks" Table A12*
V_u =	8.1	kip	OK	*Factored shear force*

Minimum Steel (ACI 350 12.13.2.1)

As,min_horiz = 0.01*b*d	1.9	in2/ft	
Provided =	2.4	in2/ft	OK
As,min_vert = 0.0025*b*d	0.5	in2/ft	
Provided =	1.4	in2/ft	OK

Slab - Minimum reinforcing per ACI 350

	t_s =	18.0 in			
	b_s =	12.0 in			

Hoop steel at 6' from wall joints (ACI 350 maximum restraint)

	A_s,req'd = 0.01*t_s*b_s	2.2 in^2	ACI 350 Table 12.13.2.1		
#7	Bar Area =	0.600 in^2	@ s =	6.00	in
	Provided =	2.4 in^2	OK		

Minimum slab steel (ACI 350 normal restraint)

	A_s,req'd = 0.005*t_s*b_s	1.08 in^2			

Hoops

#7	Bar Area =	0.600 in^2	@ s =	12.00	in
	A_s,prov =	1.2 in^2	OK		

Radial

#7	Bar Area =	0.600 in^2	@ s =	12.00	in
	A_s,prov =	1.2 in^2	OK		

Slab design for buoyant pressure

H_w =	20.00	ft	f'c =	4000	psi
t_s =	18.00	in	fy =	60000	psi
b_s =	12.00	in	$f_{s,max}$,flexure =	17000	psi
d_s =	14.50	in	E_s =	2.9E+07	psi
P_w =	62.40	pcf	E_c =	3604997	psi
H^2/Dt_s =	2.42	ft	$n = E_s/E_c$	8.04	
water pressure (q) =	218.4	psf	GWT =	3.50	ft
W_c =	150	pcf	D =	110.00	ft
DL_{slab} =	225	psf	R (from flat area) =	45.00	ft
U_F =	1.20		*Liquid pressure load factor (ACI 350)*		
U_D =	0.90		*Resisting dead load factor (ACI 350)*		

Design Load (w) =	60	psf	
S_d =	1		*Environmental durability factor*

Radial Reinforcement - At Center

	C_r =	0.2			*"Circular Concrete Tanks" Table A14*
	$M_r = C*wR^2$	24.13	kip*ft		
	$M_r/.9f'cb_sd_s^2$ =	0.032		0.030	0.002
	ω_r =	0.0314			*"Circular Concrete Tanks" Table A20*
	A_s,req'd $=\omega_r b_s d_s$(f'c/fy)	0.364	in^2		
#7	Bar Area =	0.600	in^2 @ s =	12.00 in	
	A_s,provided =	0.600	in^2	OK	

Tangential Reinforcement - At Center

	C_t =	0.2			*"Circular Concrete Tanks" Table A14*
	$M_t = C*wR^2$	24.13	kip*ft		
	$M_t/.9f'cb_sd_s^2$ =	0.032		0.030	0.002
	ω_t =	0.0314			*"Circular Concrete Tanks" Table A20*
	A_s,req'd =	0.364	in^2		
#7	Bar Area =	0.600	in^2 @ s =	12.00 in	
	A_s,provided =	0.600	in^2	OK	

Shear

$\Phi V_c = \Phi 2sqrt(f'c)b_sd_s$ =	16.5	kip	*Concrete shear capacity*
V_u = Rw/2	1.34	kip	*Shear Reinf Not Req'd*

Radial Reinforcement - At 0.2R

C_r =	0.192			"Circular Concrete Tanks" Table A14
$M_r = C*wR^2$	23.16 kip*ft			
$M_r/.9f'cb_sd_s^2$ =	0.031	0.030	0.001	
ω_r =	0.0304			"Circular Concrete Tanks" Table A20
A_s,req'd $=\omega_r b_s d_s(f'c/fy)$	0.353 in^2			
#7 Bar Area =	0.600 in^2 @ s =	12.00 in		
A_s,provided =	0.600 in^2	OK		

Radial Reinforcement - At 0.3R

C_r =	0.182			"Circular Concrete Tanks" Table A14
$M_r = C*wR^2$	21.96 kip*ft			
$M_r/.9f'cb_sd_s^2$ =	0.029	0.020	0.009	
ω_r =	0.0285			"Circular Concrete Tanks" Table A20
A_s,req'd $=\omega_r b_s d_s(f'c/fy)$	0.331 in^2			
#7 Bar Area =	0.600 in^2 @ s =	12.00 in		
A_s,provided =	0.600 in^2	OK		

Radial Reinforcement - At 0.6R

C_r =	0.128			"Circular Concrete Tanks" Table A14
$M_r = C*wR^2$	15.44 kip*ft			
$M_r/.9f'cbd^2$ =	0.020	0.020	0.000	
ωr =	0.0197			"Circular Concrete Tanks" Table A20
Asreq'd $=\omega_r bd(f'c/fy)$	0.229 in^2			
#7 Bar Area =	0.600 in^2 @ s =	12.00 in		
As,provided =	0.600 in^2	OK		

Radial Reinforcement - At 0.8R

C_r =	0.072			"Circular Concrete Tanks" Table A14
$M_r = C*wR^2$	8.69 kip*ft			
$M_r/.9f'cbd^2$ =	0.011	0.010	0.001	
ωr =	0.0109			"Circular Concrete Tanks" Table A20
Asreq'd $=\omega_r bd(f'c/fy)$	0.126 in^2			
#7 Bar Area =	0.600 in^2 @ s =	12.00 in		
As,provided =	0.600 in^2	OK		

Tangential Reinforcement - At 0.2R

	C_t =	0.196			"Circular Concrete Tanks" Table A14
	$M_t = C*wR^2$	23.65	kip*ft		
	$M_t/.9f'cbd^2$ =	0.031		0.030 0.001	
	ωt =	0.0304			"Circular Concrete Tanks" Table A20
	Asreq'd =	0.353	in^2		
#7	Bar Area =	0.600	in^2 @ s =	12.00 in	
	As,provided =	0.600	in^2	OK	

Tangential Reinforcement - At 0.4R

	C_t =	0.184			"Circular Concrete Tanks" Table A14
	$M_t = C*wR^2$	22.20	kip*ft		
	$M_t/.9f'cbd^2$ =	0.029		0.020 0.009	
	ωt =	0.0285			"Circular Concrete Tanks" Table A20
	Asreq'd =	0.331	in^2		
#7	Bar Area =	0.600	in^2 @ s =	12.00 in	
	As,provided =	0.600	in^2	OK	

Tangential Reinforcement - At 0.6R

	C_t =	0.164			"Circular Concrete Tanks" Table A14
	$Mt = C*wR^2$	19.79	kip*ft		
	$M_t/.9f'cbd^2$ =	0.026		0.020 0.006	
	ωt =	0.0256			"Circular Concrete Tanks" Table A20
	Asreq'd =	0.297	in^2		
#7	Bar Area =	0.600	in^2 @ s =	12.00 in	
	As,provided =	0.600	in^2	OK	

Tangential Reinforcement - At 0.8R

	C_t =	0.136			"Circular Concrete Tanks" Table A14
	$M_t = C*wR^2$	16.41	kip*ft		
	$M_t/.9f'cbd^2$ =	0.022		0.020 0.002	
	ωt =	0.0217			"Circular Concrete Tanks" Table A20
	Asreq'd =	0.252	in^2		
#7	Bar Area =	0.600	in^2 @ s =	12.00 in	
	As,provided =	0.600	in^2	OK	

PRCNC20240061

Owner: City of Puyallup
Project: WPCP 3rd Clarifier
Subject: Clarifier No. 3
Comp by: AQ
Checked: MJB

Radial Reinforcement

Point	Radius (ft)	C_r	M_r (kip*ft)	$M_r/.9f'cb_sd_s^2$	ω_r	A_s,req'd (in^2)	$A_s$provided (in^2)	
0.00R	0.00	0.200	24.13	0.032	0.0314	0.364	#7 @ 12.0	0.600
0.10R	4.50	0.198	23.89	0.032	0.0314	0.364	#7 @ 12.0	0.600
0.20R	9.00	0.192	23.16	0.031	0.0304	0.353	#7 @ 12.0	0.600
0.30R	13.50	0.182	21.96	0.029	0.0285	0.331	#7 @ 12.0	0.600
0.40R	18.00	0.168	20.27	0.027	0.0266	0.309	#7 @ 12.0	0.600
0.50R	22.50	0.150	18.10	0.024	0.0236	0.274	#7 @ 12.0	0.600
0.60R	27.00	0.128	15.44	0.020	0.0197	0.229	#7 @ 12.0	0.600
0.70R	31.50	0.102	12.31	0.016	0.0159	0.184	#7 @ 12.0	0.600
0.80R	36.00	0.072	8.69	0.011	0.0109	0.126	#7 @ 12.0	0.600
0.90R	40.50	0.038	4.58	0.006	0.0060	0.070	#7 @ 12.0	0.600
1.00R	45.00	0.000	0.00	0.000	0.0000	0.000	#7 @ 12.0	0.600

Tangential Reinforcement

Point	Radius (ft)	C_t	M_t (kip*ft)	$M_t/.9f'cb_sd_s^2$	ω_t	A_s,req'd (in^2)	$A_s$provided (in^2)	
0.00R	0.00	0.200	24.13	0.032	0.0314	0.364	#7 @ 12.0	0.600
0.10R	4.50	0.199	24.01	0.032	0.0314	0.364	#7 @ 12.0	0.600
0.20R	9.00	0.196	23.65	0.031	0.0304	0.353	#7 @ 12.0	0.600
0.30R	13.50	0.191	23.04	0.03	0.0295	0.342	#7 @ 12.0	0.600
0.40R	18.00	0.184	22.20	0.029	0.0285	0.331	#7 @ 12.0	0.600
0.50R	22.50	0.175	21.11	0.028	0.0275	0.319	#7 @ 12.0	0.600
0.60R	27.00	0.164	19.79	0.026	0.0256	0.297	#7 @ 12.0	0.600
0.70R	31.50	0.151	18.22	0.024	0.0236	0.274	#7 @ 12.0	0.600
0.80R	36.00	0.136	16.41	0.022	0.0217	0.252	#7 @ 12.0	0.600
0.90R	40.50	0.119	14.36	0.019	0.0188	0.218	#7 @ 12.0	0.600
1.00R	45.00	0.100	12.06	0.016	0.0159	0.184	#7 @ 12.0	0.600

Buoyancy

H_w =	20.00	ft
H_f =	18.00	ft
GWT =	5.50	ft
R =	55.00	ft
t_w =	1.33	ft
t_f=	1.00	ft
Fill angle =	60.00	deg
t_s =	1.50	ft
Length of wall =	349.8	ft
W_w =	62.40	pcf
W_c =	150	pcf
W_f =	60.00	pcf
Aw/oFooting =	9970	ft2
Atotal =	10327	ft2
Wwalls =	1399.1	kips
Wslab =	2323.5	kips
Wfill =	2529.8	kips
Wwater(up) =	3544.1	kips
FS =	1.76	OK