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Structural Calculations For:

Harbor Grove

Stormwater Detention Vault

9110 53rd Ave W

Mukilteo, WA

Prepared for: Sea Pac Homes

Job #: 12791-2023-01

Date: September 8, 2023

SEATTLE 2124 Third Avenue, Suite 100, Seattle, WA 98121
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Design Criteria

Lid Loading

vehicle loading:	HS-25	90,000 lb gross vehicle weight
min cover depth:	1	ft
max cover depth:	3	ft
design live load:	150	psf

Wall and Foundation Design

Wall and foundation design is based on the following values derived from the geotechnical report by Earth Solutions NW dated July 28, 2022:

soil density:	125	psf
at-rest soil pressure:	55	pcf EFD
active soil pressure:	35	pcf EFD
seismic surcharge:	8	H psf uniform (conservative for inverted triangular distribution)
passive pressure	300	pcf EFD (FS = 1.5)
Coefficient of Friction	0.4	(FS = 1.5)
allowbearing press:	5000	psf

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Hollow-Core Lid Plank Review

Design Criteria

soil density:	125	pcf
depth of cover:	3	ft
plank clear span:	19	ft
design live load:	150	psf

design superimposed load: 525 psf

Vault Span - Load Charts

plank simple span: 19.25 ft

HS25-44 Design Chart:			150 psf LL Design Chart:		
minimum allowable soil cover:	0.50	ft	minimum allowable soil cover:	0.50	ft
maximum allowable soil cover:	6.50	ft	maximum allowable soil cover:	6.50	ft
minimum cover w/o shear walls:	1.20	ft	minimum cover w/o shear walls:	0.50	ft
maximum cover w/o shear walls:	2.30	ft	maximum cover w/o shear walls:	5.00	ft

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Wall Design Loads

Design Criteria

maximum cover depth:	3	ft	at-rest soil pressure:	55	pcf EFD
minimum cover depth:	1	ft	active soil pressure:	35	pcf EFD
wall height:	8	ft	hydrostatic pressure:	62.4	pcf
			soil density:	125	pcf

Load Combinations

1.0 H (soil pressure) + 1.4 F (hydrostatic pressure)
1.6 H (soil pressure) + 1.6 L (surcharge/wheel load)
1.6 H (soil pressure) + 1.0 L (seismic)

Hydrostatic Pressure Check

Mu = 717 ft-lbs due to full height hydrostatic pressure
Mres = 1332 ft-lbs due to soil pressure with minimum cover
therefore reinforcing required only at inside face of wall

Soil Pressure Check

due to HS25 truck loading:
3.0 ft max cover depth: 88 psf uniform (from truck LL on walls chart)
1.0 ft min cover depth: 163 psf uniform (from truck LL on walls chart)

total factored lateral load:
3.0 ft max cover depth: 6758 plf
1.0 ft min cover depth: 6310 plf

due to uniform surcharge loading:
uniform surcharge: 150 psf
equivalent lateral: 66 psf uniform

total factored lateral load:
3.0 ft max cover depth: 6477 plf

due to seismic activity:
seismic addition: E= 8 H psf
seismic force: 64 psf Uniform

total factored lateral load:
3.0 ft max cover depth: 6144 plf

Controlling lateral load = 6758 plf
Controlling lateral load = 88 psf

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Wall Design

Design Data

soil density:	125	pcf	at-rest soil pressure:	55	pcf
soil cover depth:	3	ft	controlling lateral load:	88	psf
wall height:	8	ft			

Calculated Design Forces

Wuniform=	308	Fsur =	2464	lbs	R top =	1819	lbs	Msur = 2464
Wbot-soil=	440	Fsoil =	1760	lbs	R bot =	2405	lbs	Msoil = 1806

Ms total= 4270 ft-lbs Load Factor = 1.6 Mu = 6833 ft-lbs

Wall Design

wall thickness:	8	in	rebar strength fy =	60	ksi
rebar size:	5		conc strength f'c =	3000	psi
bar spacing:	12	in oc			
clear cover:	1.5	in	d =	6.19	in
rebar area:	0.31	sq-in	d-a/2 =	5.89	in
			calc comp block =	0.60	in

φMn = 8127 ft-lbs Mu = 6833 ft-lbs OK

Anchorage at Top of the Wall

rebar dowel size:	5		dowel strength fy=	60	ksi
dowel spacing:	12	in	conc strength f'c =	3000	psi
dowel area:	0.31	sq-in			
dowel brg length:	2	in			

shear capacity of dowel = 7363 plf Ru_{top} = 2910 plf OK

bearing capacity of dowel = 5250 plf

Anchorage at Bottom of the Wall

rebar dowel size:	5		dowel strength fy=	60	ksi
dowel spacing:	12	in	coef of friction =	0.6	smooth surface
dowel area:	0.31	sq-in			

shear friction capacity of the footing-to-wall dowel = 9388 plf Ru_{bottom} = 3849 plf OK

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Footing Design Loads

soil density:	125	pcf	uniform surcharge:	150	psf
soil cover:	3	ft	live loading:	HS25	(greater of two listed below)
wall height:	8	ft			
plank weight:	90	psf	perimeter wall cell width:	19	ft

HS-25 Load Distribution to Perimter Wall Foundation

Truck Perpendicular to the perimeter wall w/ rear axle #2 directly over wall & distance to axle #1 = 14ft

total truck load to wall = 50526 lbs

distribution width at ftg = 30 ft Load @ base of wall = 1684 plf

Truck Parallel to the perimeter wall w/ one wheel over wall & 2nd wheel on plank (incl axle 1&2 only)

total truck load to wall = 67368 lbs

distribution width at ftg = 38 ft Load @ base of wall = 1773 plf

Uniform Live Load Distribution to Wall Footings

Perimeter Wall 1425 plf

Uniform Live Load Distribution to Wall Footings

Controlling Perimeter Wall Live Load = 1773 plf

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Footing Design

Design Data

allowable bearing pressure:	5000	psf	perimeter wall cell width:	19	ft
soil desity:	125	pcf			
soil cover:	3	ft			
rebar strength fy:	60	ksi	plank weight:	90	psf
conc strength f'c:	3000	psi	wall thick:	8	in
			wall height:	8	ft

Perimeter Wall Footing Design

			Load Factor	Wu	
Design live load	1773	plf	1.6	2837	plf
Soil Cover dead load	3813	plf	1.2	4575	plf
Plank dead load	915	plf	1.2	1098	plf
Wall dead load	800	plf	1.2	960	plf
total dead load	5528	plf		6633	plf
Total live + dead Load	7300	plf		9470	plf

Required Ftg Width	1.46	ft			
Selected Ftg Width	2	ft	Selected Ftg Thickness	12	in

Qu =	4735	psf	Mu =	1052 ft-lbs	at face of wall
			Vu =	3157 plf	at face of wall
As regd =	0.03	sq-in/ft	φVn=	9498 plf	at face of wall
Asmin =	0.35	sq-in/ft			
1.33 x As reqd =	0.04	sq-in/ft			

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Grating Beam

Design Data

curb height:	1.5	ft
curb thickness:	8	in
soil density:	125	psf
beam width:	12	in
beam span:	5	ft
vehicle rear axle:	40	k

Calculated Design Forces

soil weight:	63	plf
curb weight:	150	plf
beam self-weight:	156	plf
wheel load:	20000	lbs

Load Factor:	DL	1.2
	LL	1.6

Wu =	443	plf
Pu =	32000	lbs

Flexural Design

bar size:	6	
top and bot bars:	3	
area of steel:	1.33	sq-in
depth to reinf (d):	10.13	in
comp block (a):	2.60	in
d - a/2:	8.83	in

ΦMn = 52636 ft-lbs Mu = 41383 ft-lbs

Shear Design

tie reinf size:	4	
area of steel:	0.20	
depth to reinf (d):	10.50	
max spacing:	5.25	in
reinf spacing:	5	in

ΦVc = 5176 lbs

ΦVs = 37109 lbs

ΦVc +ΦVs = 42285 lbs Vu = 33106 lbs

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Horizontal Beam at Top of Perimeter Wall @ Grating

Design Data

top of footing to inside top of vault:	8	ft	curb height:	2.1	ft
top of footing to finished grade:	11.1	ft	curb horz reinf size:	5	
soil pressure EFW:	55	pcf	curb horz reinf spacing:	12	in o/c
controlling lateral surcharge:	88	psf	depth to center of reinf:	4	in
grating span:	10	ft	curb thickness:	8	in

Calculated Design Forces

$F_{bot\ of\ curb}$ =	203.5	plf	$Mu_{horz\ curb}$ =	2544	ft-lbs	
$F_{bot\ of\ wall}$ =	698.5	plf	ϕMn_{curb} =	5107	ft-lbs	curb self-supported
$R_{top\ of\ wall}$ =	1964	plf				
Load Factor	1.6					
Wu =	3142	plf				
$Mu_{horz\ wall}$ =	39270	ft-lbs				

Horizontal Beam Design

wall thickness:	8	in
clear cover:	1.5	in
vert rebar size:	5	
rebar area:	0.31	sq-in
conc strength (f'c):	3000	psi
closure reinforcing:	(3) - #	6
As closure:	1.77	sq-in
added horizontal bar:	5	
added bar quantity:	2	
As top of wall:	0.61	sq-in
depth to reinf (d)	5.56	in
comp block (a)	2.33	in
d - a/2	4.40	in

ΦMn = 47089 ft-lbs Mu = 39270 ft-lbs

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Header Design

Header Overburden & Uniform Loads

Lid weight	90	psf
Soil Desity	125	pcf
Soil Cover depth over lid	3	ft
Plank design clear span left	8	ft
Plank design clear span right	8	ft
Design Uniform Live Load	150	psf
Lid tributary width to header	8	ft
Uniform service load to header	4920	plf
Uniform factored load to header	6384	plf

Load	Factors
LL	1.6
DL	1.2

Truck Wheel Loads to Header

Truck type	HS25	
Axle Load	40000	lbs
Wheel Spacing	8	ft
Cover depth	3.0	ft

Axle assumed centered over & perpendicular to header

distribution width	6.50	ft	opening width	6.00 ft
distribution length	15.00	ft	length ea side of hdr	7.50 ft

uniform load @ top of plank	410	psf
wheel load to header from left span	1635	plf
wheel load to header from right span	1635	plf
Total wheel load to header	3269	plf
Factored wheel load to header	5231	plf

Design Loads & Forces in Header

Service	8.2	klf
Factored	11.6	klf

Critical section for shear is at 0.9 feet from the face of the support

Design Vu =	24	k
Design Mu =	52	k-ft

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Header Design

Header Data

Header width	8	inches	Concrete Strength	3000	psi
Header span	3.00	ft			
Header depth	24	inches	d =	21.00	inches
ln/d ratio	1.71		Deep Beam limit ln/d < 5.0		

Min shear steel (Area / spacing) ratio	0.012		Min Rebar spacing
Max spacing of shear steel	4.8	inches	# 3 @ 9.17
			# 4 @ 16.67
Min horiz steel (Area / spacing) ratio	0.02		# 4 @ 10.00
Max spacing of horzontal steel	8	inches	# 5 @ 15.50

Review shear capacity of header

Reinforcing yield strength	60	ksi			
Shear reinforcing area	0.20	sq in	Horz reinf area	0.31	sq in
spacing	6	in	Horz reinf spacing	12	in
Reinf shear capacity ΦVs	34	k	Conc shear capacity ΦVc	16	k

Total Shear Capacity	49	k	Factored shear Vu 24 k
Max ΦVn @ ln/d < 2	63	k	
Max ΦVn @ 2 < ln/d < 5	7016	k	

Review flexural capacity of header

min As based on 200 bwd/fy	0.56	sq inches	
min As based on eq 10-3	0.46	sq inches	
As reqd based on bending model	0.61	sq inches	- Provide (2)-#6 above opng

As reqd based on tie - strut model
assume Vu is focused @ the center of the header

then Tu =	44.80	k
As reqd =	0.83	sq inches

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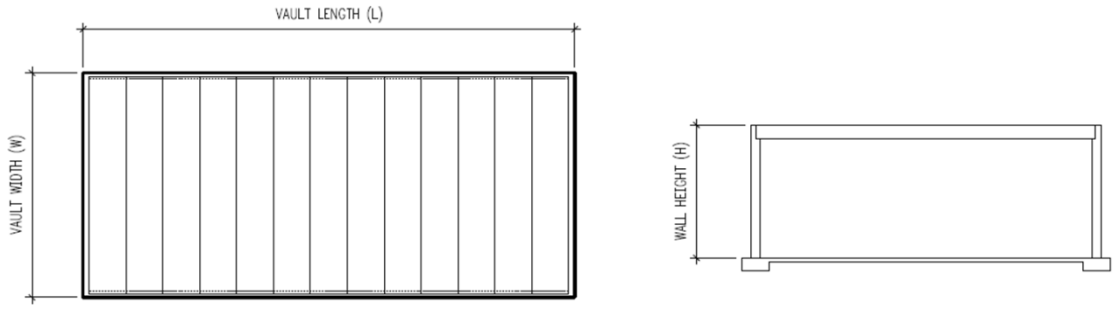
Seismic Analysis

Vault Geometry



vault length:	119 ft	soil density:	125 pcf	wall height:	9 ft	f'c:	3000 psi
vault width:	21 ft	wall thickness:	8 in	vert reinf:	5	fy:	60 ksi
soil cover:	2.5 ft	number of cells:	1	vert reinf spacing:	12 " o/c		

Structure Dead Load Tributary to the Lid

weight of soil:	781 k	
weight of lid:	225 k	
weight of walls:	126 k	
total structure dead load:	1132 k	

Seismic Review:

IBC Site Class: D

Design Spectral Response Accel (Sds): 1.00
Response Modification Factor: 4.0 for Ordinary Reinforced Concrete Shear Walls

1.2(Sds)/R = 0.300 V = 340 k

shear distributed over 90% of shortest length of wall (d assumed to be 90% of vault width):

v = 8.98 klf

φvc + φvs = 17.35 klf OK

Shear capacity of concrete:
φvc = 6.31 klf

Shear capacity of reinforcing:
φvs = 11.04 klf

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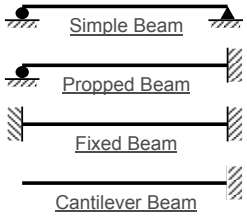
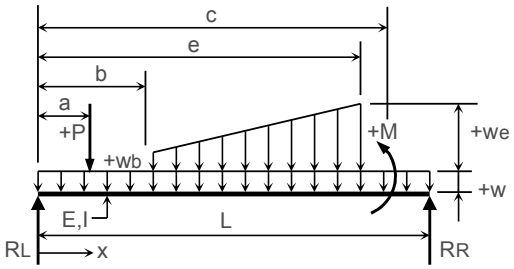
Grate Beam Design

Beam Data:

Span Type?	Simple	
Span, L =	10.0000	ft.
Modulus, E =	29000	ksi
Inertia, Ix =	96.30	in.^4
Beam Size =	W10x19	
Yield, Fy =	50	ksi
Length, Lb =	3.0000	ft.
Coef., Cb =	1.00	





Nomenclature

Beam Loadings:

Full Uniform:

w = 0.0680 kips/ft.

Distributed:

	Start b (ft.)	Start Wb (kips/ft.)	End e (ft.)	End We (kips/ft.)
#1:				
#2:				
#3:				
#4:				
#5:				
#6:				
#7:				
#8:				

Moments:

	c (ft.)	M (ft-kips)
#1:		
#2:		
#3:		
#4:		

Point Loads:

	a (ft.)	P (kips)
#1:	5.0000	20.00
#2:		
#3:		
#4:		
#5:		
#6:		
#7:		
#8:		
#9:		
#10:		
#11:		
#12:		
#13:		
#14:		
#15:		

Results:

End Reactions:

RL =	10.34	kips	RR =	10.34	kips
MxL =	N.A.	ft-kips	MxR =	N.A.	ft-kips

Maximum Moments:

+Mx(max) =	50.85	ft-kips	@ x =	5.00	ft.
-Mx(max) =	0.00	ft-kips	@ x =	0.00	ft.

Maximum Deflections:

-Δ(max) =	-0.263	in.	@ x =	5.00	ft.
+Δ(max) =	0.000	in.	@ x =	0.00	ft.
Δ(ratio) =	L/456				

AISC Code Check for X-Axis Bending:

Lc =	3.60	ft.
Lu =	5.17	ft.
Lb/rt =	34.95	
fbx =	32.46	ksi
Fbx =	33.00	ksi
Mrx =	51.70	ft-kips
S.R. =	0.984	= fbx/Fbx

AISC Code Check for Gross Shear:

fv =	4.05	ksi
Fv =	20.00	ksi
S.R. =	0.203	= fv/Fv

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19 Space
(1-3/16") Load Table

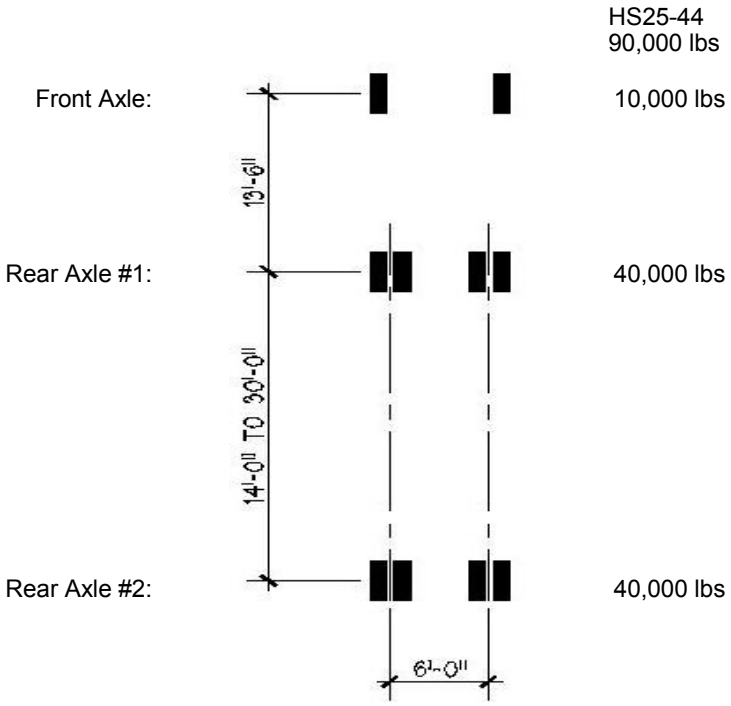
Use this table when evaluating spans & loads for the following types of Heavy Duty steel grating:

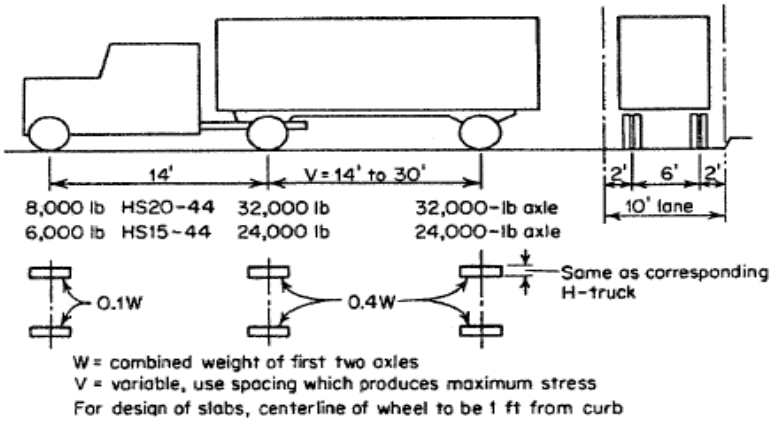
19-W-4 and 19-W-2

H-25 Load | H-20 Load | H-15 Load | Auto Traffic | 5 Ton Forklift | 3 Ton Forklift | 1 Ton Forklift

				Maximum Safe Span						
Bearing Bar Size (inches)	Section Modulus per foot of width	Moment of Inertia perfoot of width	Approx. Weight psf	H-25 Load	H-20 Load	H-15 Load	Auto Traffic	5 Ton Forklift	3 Ton Forklift	1 Ton Forklift
1 x 1/4	0.421	0.211	9.7	1'-0"	0'-10"	0'-9"	1'-0"	0'-7"	0'-6"	0'-7"
1 x 5/16	0.526	0.263	11.9	1'-1"	1'-0"	0'-10"	1'-2"	0'-8"	0'-7"	0'-8"
1 x 3/8	0.632	0.316	14.0	1'-2"	1'-1"	0'-11"	1'-4"	0'-9"	0'-8"	0'-9"
1-1/4 x 1/4	0.658	0.411	11.9	1'-3"	1'-1"	1'-0"	1'-5"	0'-9"	0'-8"	0'-10"
1-1/4 x 5/16	0.822	0.514	14.5	1'-4"	1'-3"	1'-1"	1'-8"	0'-10"	0'-9"	1'-0"
1-1/4 x 3/8	0.987	0.617	17.2	1'-6"	1'-4"	1'-2"	1'-11"	1'-0"	0'-10"	1'-2"
1-1/2 x 1/4	0.947	0.711	14.0	1'-6"	1'-4"	1'-2"	1'-11"	0'-11"	0'-10"	1'-1"
1-1/2 x 5/16	1.184	0.888	17.2	1'-8"	1'-6"	1'-4"	2'-3"	1'-1"	0'-11"	1'-4"
1-1/2 x 3/8	1.421	1.066	20.4	1'-10"	1'-8"	1'-6"	2'-6"	1'-2"	1'-1"	1'-7"
1-3/4 x 1/4	1.289	1.128	16.2	1'-9"	1'-7"	1'-5"	2'-5"	1'-2"	1'-0"	1'-5"
1-3/4 x 5/16	1.612	1.410	19.9	1'-11"	1'-9"	1'-7"	2'-11"	1'-4"	1'-3"	1'-9"
1-3/4 x 3/8	1.934	1.692	23.7	2'-2"	1'-11"	1'-9"	3'-2"	1'-6"	1'-5"	2'-1"
2 x 1/4	1.684	1.684	18.3	2'-0"	1'-10"	1'-8"	3'-1"	1'-4"	1'-3"	1'-10"
2 x 5/16	2.105	2.105	22.6	2'-3"	2'-1"	1'-11"	3'-6"	1'-7"	1'-6"	2'-4"
2 x 3/8	2.526	2.526	26.9	2'-6"	2'-4"	2'-2"	3'-10"	1'-10"	1'-9"	2'-9"
2-1/4 x 1/4	2.132	2.398	20.4	2'-3"	2'-1"	1'-11"	3'-9"	1'-7"	1'-6"	2'-4"
2-1/4 x 5/16	2.664	2.998	25.3	2'-7"	2'-5"	2'-3"	4'-2"	1'-11"	1'-10"	2'-11"
2-1/4 x 3/8	3.197	3.597	30.1	2'-10"	2'-8"	2'-7"	4'-5"	2'-2"	2'-2"	3'-5"
2-1/2 x 1/4	2.632	3.289	22.6	2'-6"	2'-4"	2'-3"	4'-4"	1'-10"	1'-10"	2'-10"
2-1/2 x 5/16	3.289	4.112	28.0	2'-11"	2'-9"	2'-7"	4'-8"	2'-3"	2'-3"	3'-6"
2-1/2 x 3/8	3.947	4.934	33.3	3'-4"	3'-2"	3'-0"	4'-11"	2'-7"	2'-7"	4'-2"
3 x 1/4	3.789	5.684	26.9	3'-3"	3'-1"	2'-11"	5'-2"	2'-6"	2'-6"	4'-1"
3 x 5/16	4.737	7.105	33.3	3'-9"	3'-7"	3'-6"	5'-7"	3'-0"	3'-1"	4'-9"
3 x 3/8	5.684	8.526	39.8	4'-4"	4'-2"	4'-1"	5'-11"	3'-7"	3'-8"	5'-1"
3-1/2 x 1/4	5.158	9.026	31.2	4'-0"	3'-10"	3'-9"	6'-0"	3'-3"	3'-4"	5'-2"
3-1/2 x 5/16	6.447	11.283	38.7	4'-9"	4'-8"	4'-7"	6'-6"	4'-0"	4'-1"	5'-7"
3-1/2 x 3/8	7.737	13.539	46.2	5'-0"	5'-0"	5'-0"	6'-11"	4'-8"	4'-10"	5'-11"
4 x 1/4	6.737	13.474	35.5	4'-11"	4'-10"	4'-9"	6'-11"	4'-2"	4'-3"	5'-11"
4 x 5/16	8.421	16.842	44.1	5'-5"	5'-5"	5'-5"	7'-5"	5'-1"	5'-3"	6'-4"
4 x 3/8	10.105	20.211	52.7	5'-8"	5'-8"	5'-9"	7'-11"	5'-6"	5'-8"	6'-9"
4-1/2 x 1/4	8.526	19.184	39.8	5'-7"	5'-7"	5'-8"	7'-9"	5'-1"	5'-4"	6'-8"
4-1/2 x 5/16	10.658	23.980	49.4	6'-0"	6'-0"	6'-1"	8'-4"	5'-10"	6'-0"	7'-2"
4-1/2 x 3/8	12.789	28.776	59.1	6'-5"	6'-5"	6'-5"	8'-11"	6'-2"	6'-4"	7'-7"
5 x 1/4	10.526	26.316	44.1	6'-3"	6'-3"	6'-3"	8'-8"	6'-0"	6'-2"	7'-5"
5 x 3/8	15.789	39.474	65.5	7'-1"	7'-1"	7'-2"	9'-11"	6'-11"	7'-1"	8'-6"
5 x 1/2	21.053	52.632	87.0	7'-10"	7'-10"	7'-11"	10'-11"	7'-7"	7'-9"	9'-4"
6 x 1/4	15.158	45.474	52.7	7'-5"	7'-5"	7'-6"	10'-4"	7'-3"	7'-5"	8'-11"
6 x 3/8	22.737	68.211	78.4	8'-6"	8'-6"	8'-7"	11'-10"	8'-3"	8'-6"	10'-2"
6 x 1/2	30.316	90.947	104.2	9'-4"	9'-4"	9'-5"	13'-1"	9'-1"	9'-4"	11'-2"
7 x 1/4	20.632	72.211	61.2	8'-8"	8'-8"	8'-9"	12'-1"	8'-5"	8'-8"	10'-4"
7 x 3/8	30.947	108.316	91.3	9'-11"	9'-11"	10'-0"	13'-10"	9'-8"	9'-11"	11'-10"
7 x 1/2	41.263	144.421	121.4	10'-10"	10'-11"	11'-0"	15'-3"	10'-7"	10'-11"	13'-1"

Appendix: HS25-44 Loading





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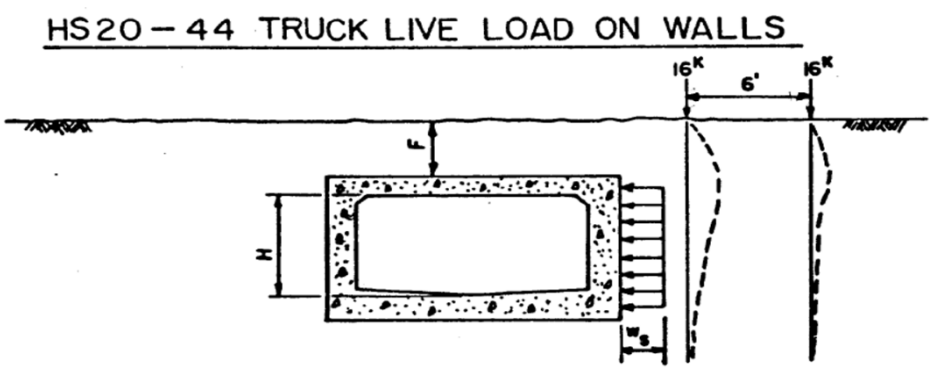
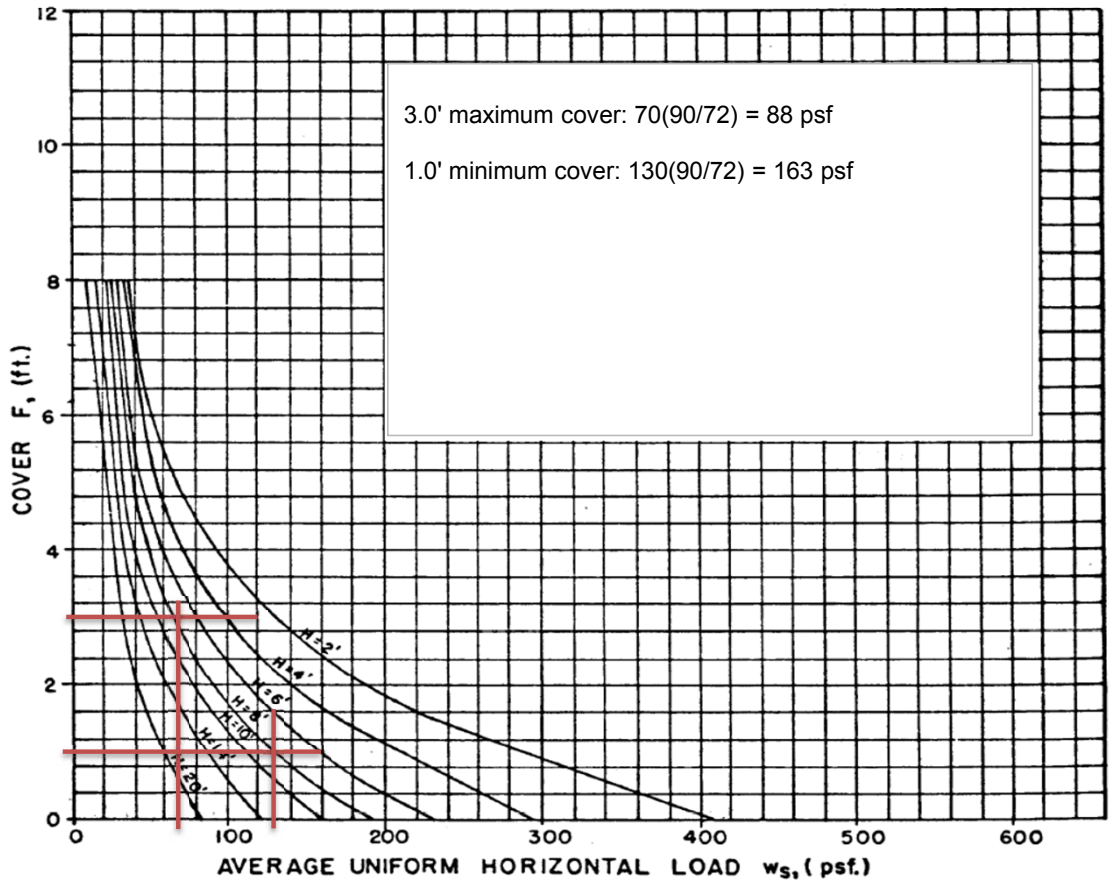
Appendix: HS25-44 Loading on Walls





Project: Harbor Grove

Date: 9/8/2023
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Design: RJA
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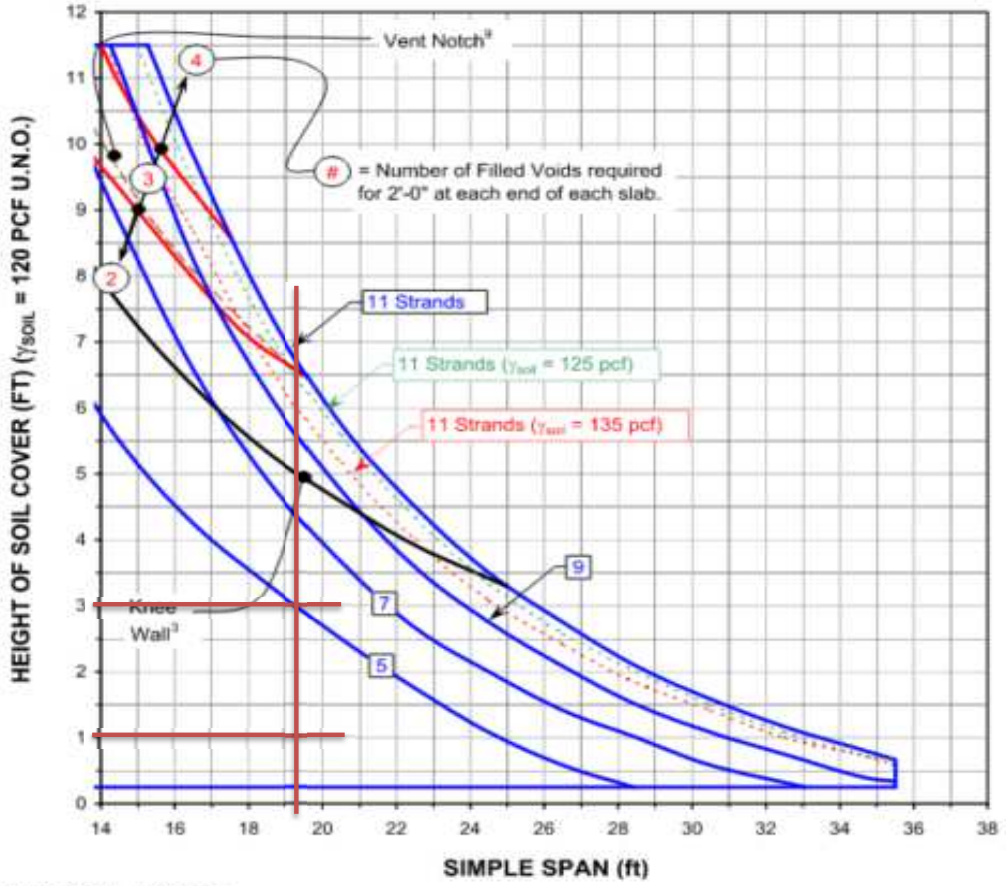
Appendix: 150psf Uniform LL Design Charts

CONCRETE TECHNOLOGY CORPORATION

12½" HOLLOW CORE SLAB
150 PSF



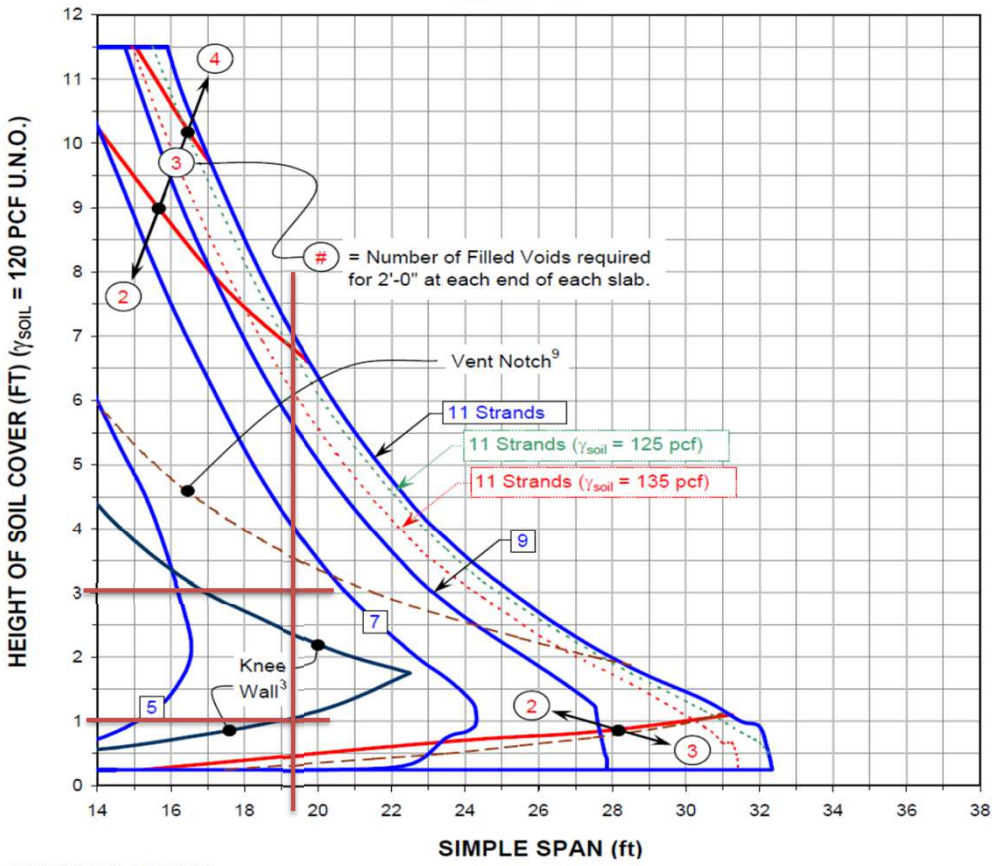
GENERAL NOTES:

1.) A minimum cover depth of six inches OR a three inch thick cast in place concrete topping slab is required.
2.) Simple Span is centerline of bearing to centerline of bearing.
3.) The Knee Wall envelope represents the maximum span and height of soil cover that can be supported by slabs with standard notches for manhole openings, assuming void fill concrete f'c = 3,000 psi. Points falling outside this envelope require knee walls to support the slabs at manhole openings.
4.) Interpolation between strand contours is acceptable. DO NOT extrapolate beyond the bounds of this chart.
5.) Soil cover is assumed to be uniform.
6.) Except as noted, soil cover unit weight is assumed to be 120 pcf.
7.) Minimum span length = 14'-0".
8.) The values shown on this chart are in compliance with IBC 2003 & ACI 318-05.
9.) The Vent Notch envelope represents the maximum span and height of soil cover that can be supported by slabs with 6½" standard notches in adjacent slabs to accommodate 12" diameter vents, assuming void fill concrete f'c = 3,000 psi. Refer to Detail 3 on page 15 of this brochure for vent notch details.

Appendix: HS25 LL Design Charts

CONCRETE TECHNOLOGY CORPORATION

12½" HOLLOW CORE SLAB
HS25-44



GENERAL NOTES:

1.) A minimum cover depth of six inches OR a three inch thick cast in place concrete topping slab is required.
2.) Simple Span is centerline of bearing to centerline of bearing.
3.) The Knee Wall envelope represents the maximum span and height of soil cover that can be supported by slabs with standard notches for manhole openings, assuming void fill concrete f'c = 3,000 psi. Points falling outside this envelope require knee walls to support the slabs at manhole openings.
4.) Interpolation between strand contours is acceptable. DO NOT extrapolate beyond the bounds of this chart.
5.) Soil cover is assumed to be uniform.
6.) Except as noted, soil cover unit weight is assumed to be 120 pcf.
7.) Minimum span length = 14'-0".
8.) The values shown on this chart are in compliance with IBC 2003 & ACI 318-05.
9.) The Vent Notch envelope represents the maximum span and minimum/maximum height of soil cover that can be supported by slabs with 6½" standard notches in adjacent slabs to accommodate 12" diameter vents, assuming void fill concrete f'c = 3,000 psi. Refer to Detail 3 on page 15 of this brochure for vent notch details.