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Donald Lum ES Liquefaction Evaluation Structural Calculations

Alameda, California
ZFA Project Number: 17135

Donald Lum ES Liquefaction Evaluation

May 16, 2017

Prepared For:
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STRUCTURAL NARRATIVE

Donald Lum Elementary School is a part of Alameda Unified School District located in Alameda, California. There are five buildings on the campus connected by covered walkways. The buildings consist of wood and steel framing with wood and masonry vertical elements.

Miller Pacific Engineering Group performed soil testing at the site and subsequent liquefaction analysis. They found a high risk of liquefaction at the site with potential differential settlement between 3 to 7 inches across a given building footprint.

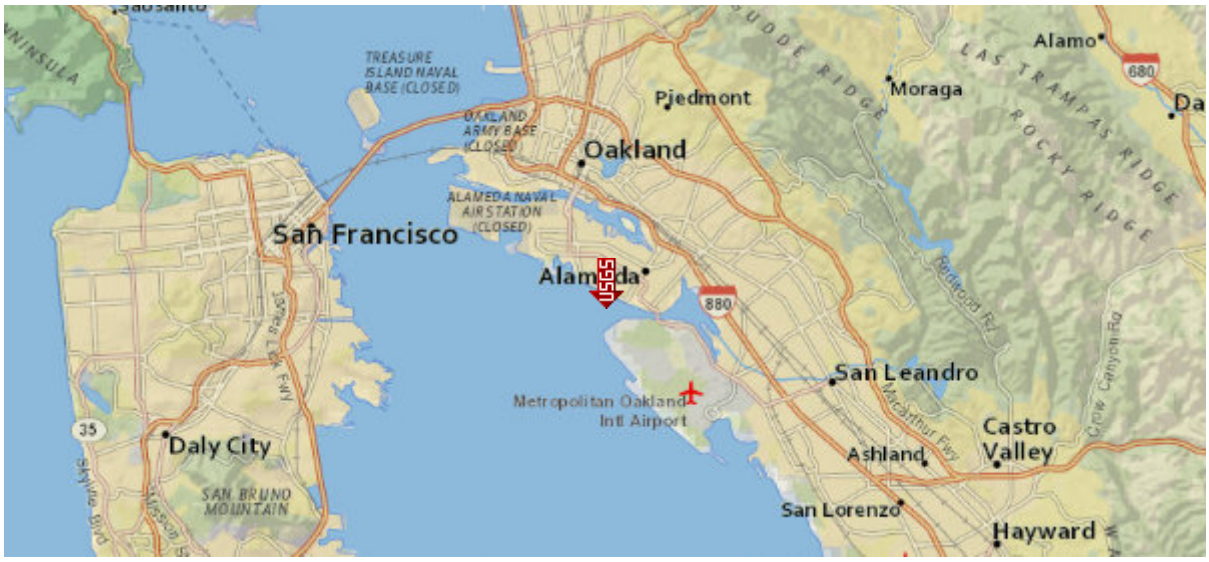
To evaluate the effects of liquefaction at the site we analyzed perimeted and interior footings for a 25 foot diameter loss of bearing at each building.

The existing footings were not designed for this loss of bearing at the foundations and our anylsis indicates the footings do not have sufficient capacity to sustain the loss of bearing.

USGS Design Maps Summary Report

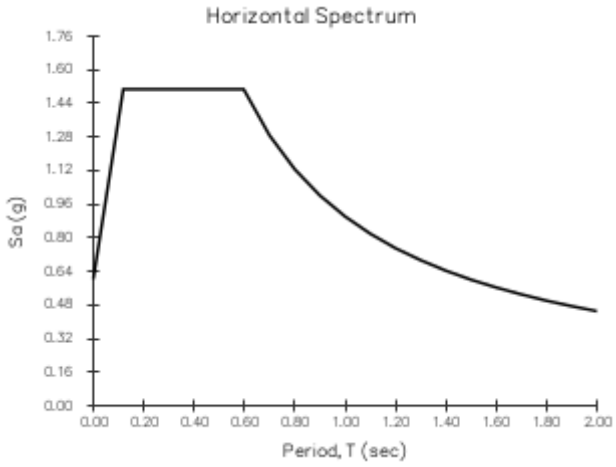
User–Specified Input

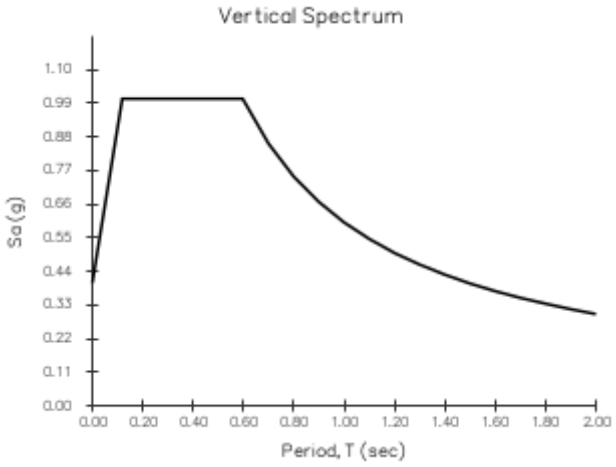
Report Title	Donald Lum ES Tue May 16, 2017 00:58:54 UTC
Building Code Reference Document	ASCE 41-13 Retrofit Standard, BSE-2N (which utilizes USGS hazard data available in 2008)
Site Coordinates	37.76169°N, 122.26024°W
Site Soil Classification	Site Class D – "Stiff Soil"



USGS–Provided Output

$S_{S,BSE\text{-}2N}$	1.507 g	$S_{XS,BSE\text{-}2N}$	1.507 g
$S_{1,BSE\text{-}2N}$	0.600 g	$S_{X1,BSE\text{-}2N}$	0.901 g

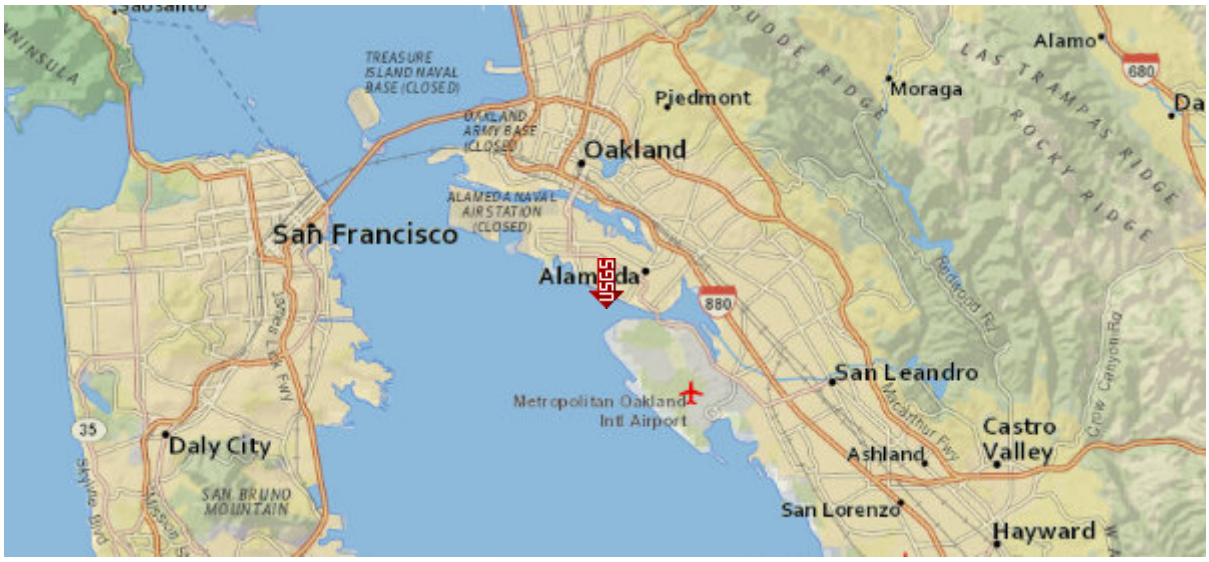




USGS Design Maps Summary Report

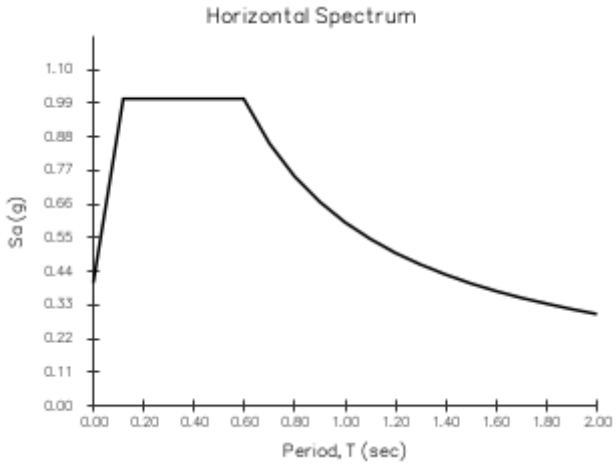
User–Specified Input

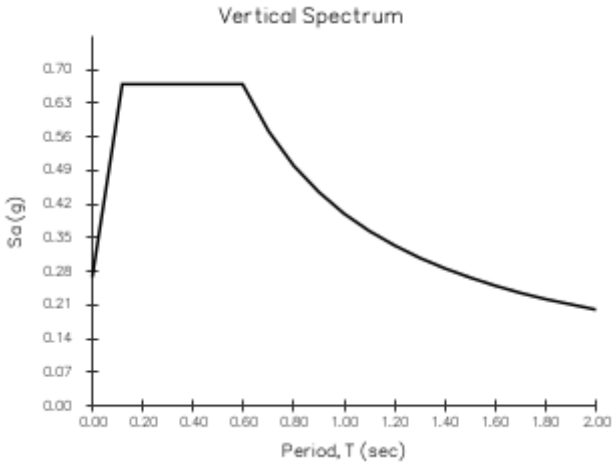
Report Title	Donald Lum ES Tue May 16, 2017 00:59:22 UTC
Building Code Reference Document	ASCE 41-13 Retrofit Standard, BSE-1N (which utilizes USGS hazard data available in 2008)
Site Coordinates	37.76169°N, 122.26024°W
Site Soil Classification	Site Class D – "Stiff Soil"



USGS–Provided Output

$S_{XS,BSE-1N}$	1.005 g
$S_{X1,BSE-1N}$	0.600 g





$Q_6 = 1.1 (Q_D + Q_L)$

Q_L = 25% UNREDUCED ASCE 7 LIVE LOAD

= 0.25 * 50 PSF (2016 CBC TABLE 1607A.1 FOOTNOTE P)

= 12.5 PSF

- ASSUME FIXED-FIXED FOR FOUNDATION SPANNING.
- SIMPLIFY SLAB LOAD TO TRIANGULAR RATHER THAN SEMI-CIRCLE

SLAB TRIBUTARY IS $\frac{25\ FT}{2}$ = 12.5 FT INTERIOR

10 FT EXTERIOR

1959 CLASSROOM 1 & 2

VERTICAL LOADS

EXTERIOR WALL – CMU

HT = 9.75 FT

WT = 80 PSF = 780 PLF

EXTERIOR WALL – STOREFRONT

HT = 9 FT

WT = 10 PSF = 90 PLF

ROOF WEIGHT

19 PSF

TRIB = 4.5 + $\frac{11}{2}$ = 10 FT

= 19 * 10 = 190 PLF

FOUNDATION – EXTERIOR WALL

2'-8" DEEP 1'-6" WIDE

(1)#6 T&B #4 @ 12" oc VERT

WT = $\frac{18}{12} * \frac{32}{12} * 150$ PCF

= 600 PLF

SLAB

4" #4 @ 18" oc EA WAY

WT = $\frac{4}{12} * 150$ PCF

= 50 PSF

LATERAL LOADS

TOTAL SEISMIC WEIGHT

= 215 K

TOTAL ROOF AREA

= 8,587 SF

TRIBUTARY ROOF AREA

= 727 SF + 1/2 * 2819 SF

= 2137 SF

TRIBUTARY SEISMIC WEIGHT

= $\frac{2137}{8587} * 215$ K

= 53.5 K

157 CLASSROOM 1 & 2 - CONT'D

BSE-2 $Q_{up} = 1.5W$
$= 1.5 * 45\ K$
$= 68\ K$

BSE-2 $M_{OT} = V * lt$
$= 68\text{-}K * 9.75\ FT$
$= 661\ K\text{-}FT$

$\frac{M}{S} = \frac{661\ K\text{-}FT}{1.5 * (12")^2 / 6} * 1.5\ FT = 28\ KLF$

BSE-2 $\frac{Q_{UP}}{5} = \frac{28}{2} = 14\ KLF$

CHECK FOOTING W/O BLOCK WALL, AT 6.5 FT & 18.5 FT

BSE-2 Q_{UF} = 68.1 K-FT @ 6.5 FT
34 K-FT @ 18.5 FT 198.1 K-FT @ 0 FT
(SEE RISA)

(E) FOOTING CAPACITY

$d = 32" - 3" - \frac{1}{2} * \frac{6}{8}"$
$= 28.625"$

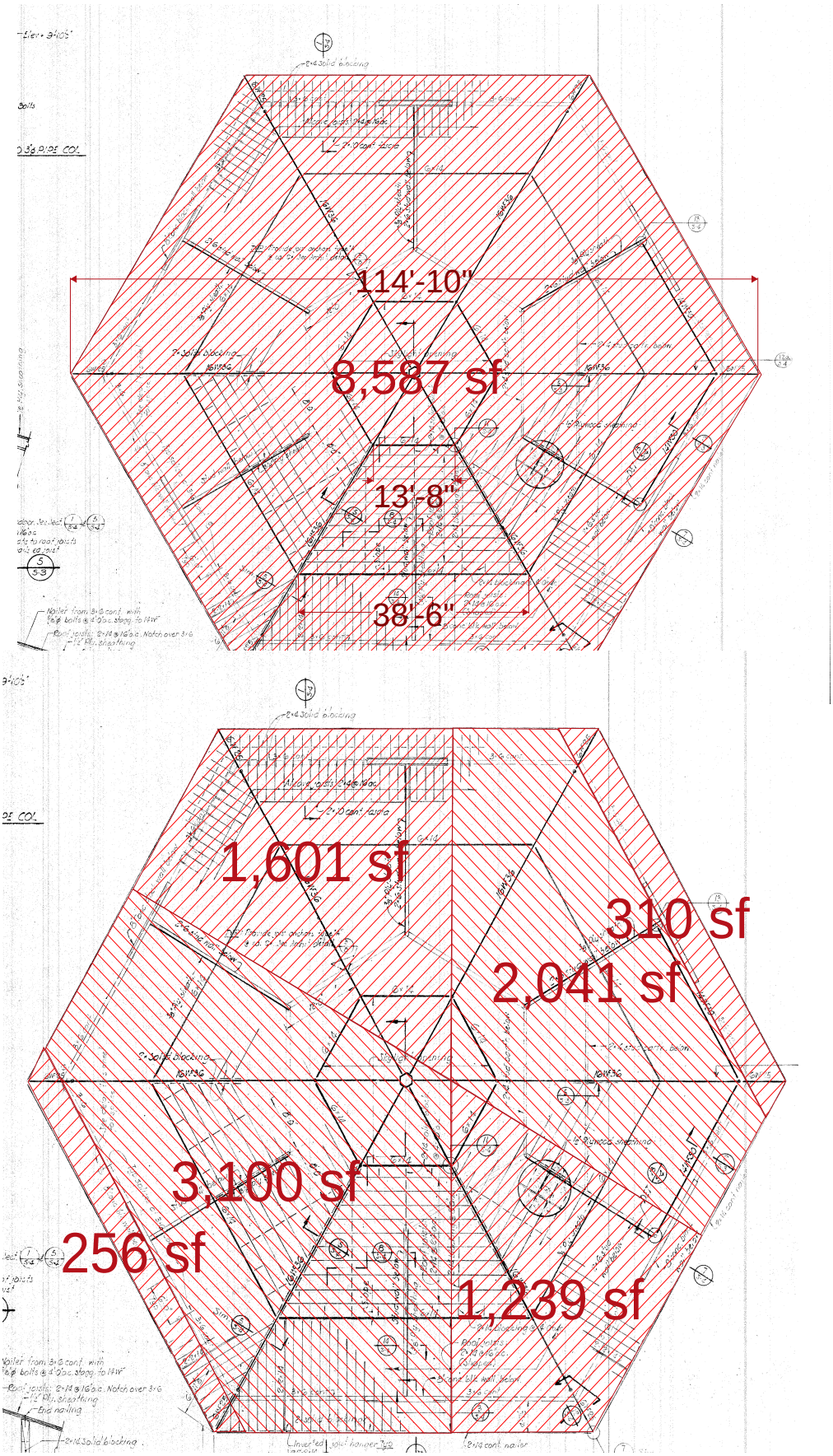
$f_{yL} = 33\ KSI$ (ASSUMED)
$f'_c = 2000\ PSI$ (S9)

$a = \frac{A_s f_y}{0.85 f'_c b}$
$= \frac{(1) * 0.44\ IN^2 * 33\ KSI}{0.85 * 2\ KSI * 18\ IN} = 0.47$

$Q_{LL} = A_s f_y (d - a/2)$
$= 0.44 * 33 * (28.625 - \frac{0.47}{2})$
$= 34.3\ K\text{-}FT$

BSE-2 $\frac{Q_{UF}}{Q_{LL}} = \frac{198}{34} = 5.8$

1959 Classroom



Site Criteria

Latitude =	37.76169
Longitude =	-122.26024

Site Class =	D	[per Geotechnical Report]
Fa =	1	
Fv =	1.5	

BSE2 Response Spectra (2% in 50 year period)

S_S =	1.51	USGS Seismic Design Maps	F_a =	1.00
S_1 =	0.60	USGS Seismic Design Maps	F_v =	1.50
S_{XS} =	1.51	[F_a * S_S]		
S_{X1} =	0.90	[F_v * S_1]		

BSE1 Response Spectra (10% in 50 year period)

S_S =	1.005	USGS Seismic Design Maps	F_a =	1.10
S_1 =	0.4	USGS Seismic Design Maps	F_v =	1.50
S_{XS} =	1.00	[F_a * S_S]		
S_{X1} =	0.60	[F_v * S_1]		

Building Period (Method 2 - Empirical)

T =	[Ct * hnβ]	
T =	0.17 sec	
C_t =	0.02	
h_n =	17.0 ft	[mean building height]
β =	0.75	

Horizontal Response Acceleration

	BSE2		*BSE1*	
T_s =	0.60		0.60	[S_{X1} / S_{XS}]
T_0 =	0.12		0.12	[0.2 * T_S]
B_1 =		1.00		[4 / {5.6 - ln(100 * 0.05)}]
S_a =	1.50		1.00	[S_{XS} / B_1]

HIGH Level of Seismicity

Pseudo Lateral Force

		BSE2	*BSE1*	
V =		$C_1C_2C_mS_aW$		
V =		1.50 * W	1.00 * W	with $C_1 = C_2 = C_m = 1.0$
$DCR_{max} = Q_{UD}/Q_{CE}$ =			2.50	(see following calculations)
C_m =		1.0		[1.0 for 1-2 stories]
a =		60		[per Site Class]
R =		$[DCR_{max} * C_m / 1.5 >= 1.0]$		
R =		1.67		
C_1 =		$[1+ (R - 1) / (a * T^2)]$		*(T_{min} = 0.2)*
C_2 =		$[1 + \{(R - 1) / T\}^2 / 800]$		
C_1 =		1.28		
C_2 =		1.02		

		BSE2'	*BSE1'*	
V' =		$C_1C_2C_mS_aW$		
V' =		1.96 * W	1.31 * W	with C_1, C_2, C_m as calculated above

Roof Area = **8587 sf** *(Includes Overhang)*

Diaphragm: Roof Slope: 3.25:12 Slope Factor: **1.04**

Roof Materials	PSF	x Roof Area =	Diaphragm Wt
Built up roofing	6.0		53 kips
1/2" Plywood	1.5		13 kips
2x14 Wood Rafters @ 24"oc	3.0		27 kips
W16x36	1.4		13 kips
6x14	0.7		6 kips
M/E/P	1.5		13 kips
Ceiling	1.5		13 kips
Insulation	1.0		9 kips
Misc.	2.4		21 kips
Total	19.0	Sum =	169 kips

1) Diaphragm weights include the diaphragm and half of the height of out-of-plane walls.

2) Seismic wall weights include half height of wall.

Ext Walls

Line	Elements	PSF	x Length (ft)or Quantity	x Height (ft)	= Wall Weight	Diaphragm Wall Wt
1	8" CMU Wall	80	12	9.8	9 kips	5 kips
	Window	10	38	9.0	3 kips	2 kips
				Sum =	13 kips	6 kips

Line	Elements	PSF	x Length (ft)or Quantity	x Height (ft)	= Wall Weight	Diaphragm Wall Wt
2	8" CMU Wall	80	12	9.8	9 kips	5 kips
	Door/Partition	10	38	9.0	3 kips	2 kips
				Sum =	13 kips	6 kips

Line	Elements	PSF	x Length (ft)or Quantity	x Height (ft)	= Wall Weight	Diaphragm Wall Wt
3	8" CMU Wall	80	12	9.8	9 kips	5 kips
	Door	10	38	9.0	3 kips	2 kips
				Sum =	13 kips	6 kips

Line	Elements	PSF	x Length (ft)or Quantity	x Height (ft)	= Wall Weight	Diaphragm Wall Wt
4	8" CMU Wall	80	12	9.8	9 kips	5 kips
	Window	10	38	9.0	3 kips	2 kips
				Sum =	13 kips	6 kips

Line	Elements	PSF	x Length (ft)or Quantity	x Height (ft)	= Wall Weight	Diaphragm Wall Wt
5	8" CMU Wall	80	12	9.8	9 kips	5 kips
	Window	10	38	9.0	3 kips	2 kips
				Sum =	13 kips	6 kips

Line	Elements	PSF	x Length (ft)or Quantity	x Height (ft)	= Wall Weight	Diaphragm Wall Wt
6	8" CMU Wall	80	12	9.8	9 kips	5 kips
	Window	10	38	9.0	3 kips	2 kips
				Sum =	13 kips	6 kips

Int Walls

Line	Elements	PSF	x	Length (ft)or Quantity	x	Height (ft)	=	Wall Weight	Diaphragm Wall Wt
1	Wood Framed Wall	15		24		13.0		5 kips	2 kips
						Sum =		5 kips	2 kips

Line	Elements	PSF	x	Length (ft)or Quantity	x	Height (ft)	=	Wall Weight	Diaphragm Wall Wt
2	Wood Framed Wall	15		24		13.0		5 kips	2 kips
						Sum =		5 kips	2 kips

Line	Elements	PSF	x	Length (ft)or Quantity	x	Height (ft)	=	Wall Weight	Diaphragm Wall Wt
3	Wood Framed Wall	15		24		13.0		5 kips	2 kips
						Sum =		5 kips	2 kips

Line	Elements	PSF	x	Length (ft)or Quantity	x	Height (ft)	=	Wall Weight	Diaphragm Wall Wt
4	Wood Framed Wall	15		24		13.0		5 kips	2 kips
						Sum =		5 kips	2 kips

Line	Elements	PSF	x	Length (ft)or Quantity	x	Height (ft)	=	Wall Weight	Diaphragm Wall Wt
5	Wood Framed Wall	15		24		13.0		5 kips	2 kips
						Sum =		5 kips	2 kips

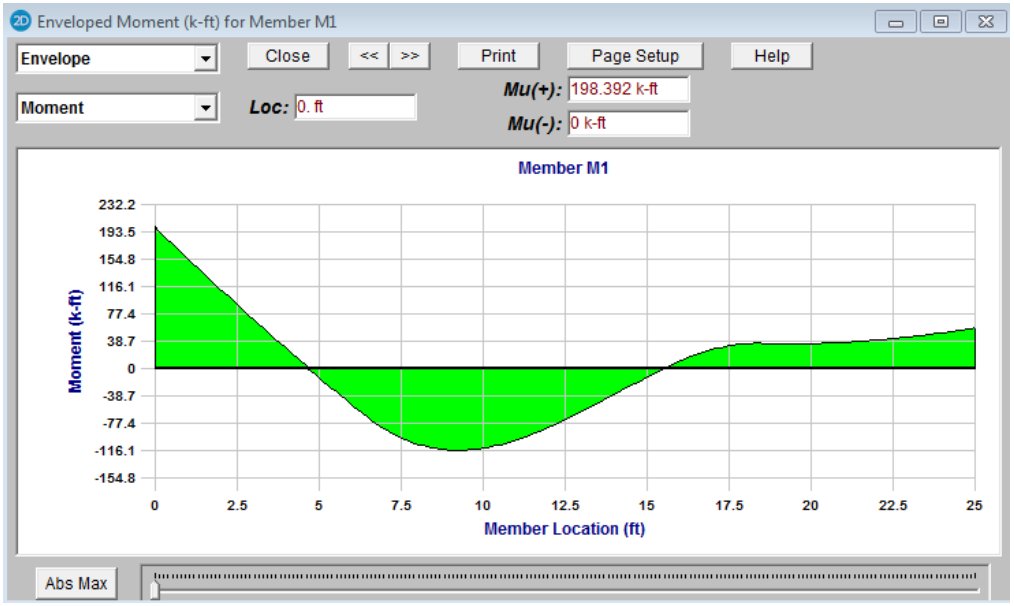
Line	Elements	PSF	x	Length (ft)or Quantity	x	Height (ft)	=	Wall Weight	Diaphragm Wall Wt
6	Wood Framed Wall	15		24		13.0		5 kips	2 kips
						Sum =		5 kips	2 kips

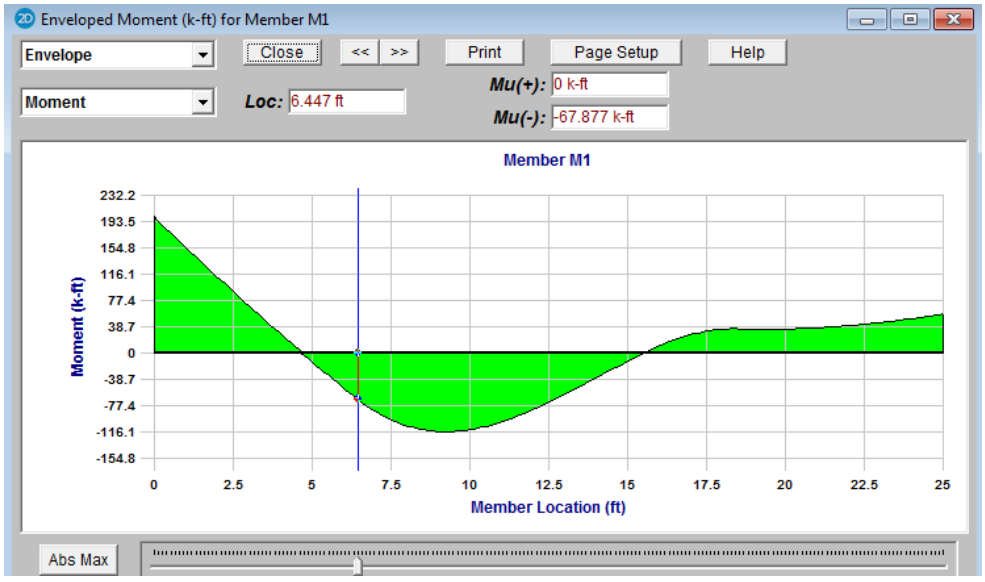
Weight Summary:

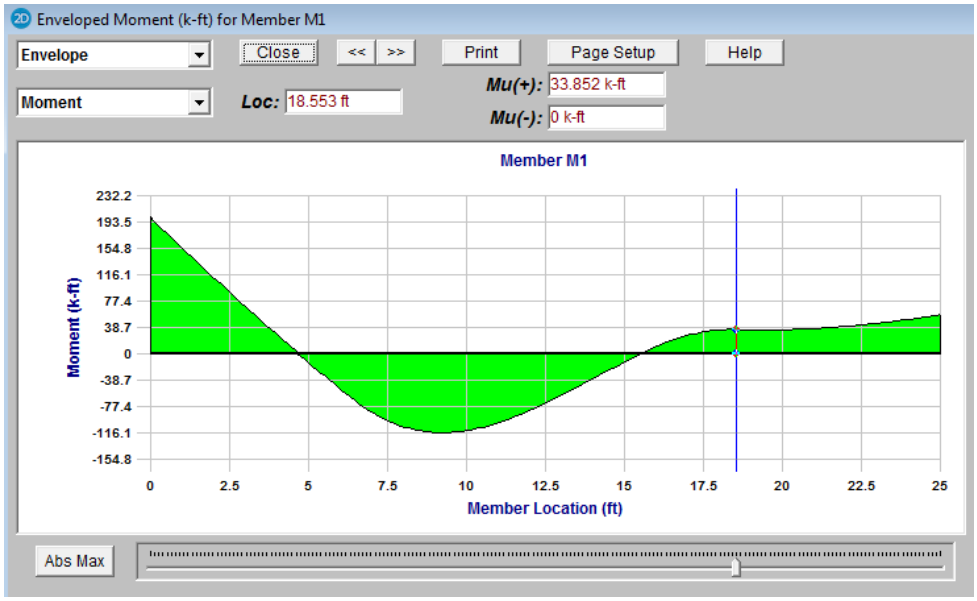
Diaphragm Weights

Diaphragm Weight = **215 kips**

1959 Classroom







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1959 MULTI-USE

EXTERIOR CMU WALL NW OF BUILDING

VERTICAL LOADS

EXTERIOR WALL - CMU

WT = 80 PSF
HT = 8.67 FT
WT = 694 PLF

EXTERIOR WALL - STORE FRONT

WT = 10 PSF
HT = 9 FT
WT = 90 PLF

ROOF WEIGHT

WT = 18 PSF
TRIB = 15 FT
WT = 270 PLF

FOUNDATION

2'-8" DEEP 1'-6" WIDE (1) #6 T&B #4 @ 12" o.c. VERT

$WT = \frac{32}{12} * \frac{18}{12} * 150$
$= 600$ PLF

SLAB

4" #4 @ 18" OC EW

$WT = \frac{4}{12} * 150$
$= 50$ PSF

MAX WT = 50 PSF * 25 FT
= 1250 PLF

MAX LL = 12.5 PSF * 25 FT
= 313 PLF

@ MODEL SLAB & LIVE LOAD AS TRIANGULAR DISTRIBUTION W/ 25 FT TRIB FROM PEAK TO PEAK IN EITHER SIDE AT MIDDLE OF FIN

LATERAL LOADS

TOTAL SEISMIC WT = 306 k
TOTAL ROOF AREA = 12095 SF
TRIBUTARY ROOF AREA = 163 SF + $\frac{1}{2}$ * 3358 SF + $\frac{1}{2} * \frac{1}{2}$ * 4619 SF
= 2997 SF

1959 MULTI-USE CONT'D

TRIBUTARY SEISMIC WT = $\frac{2997}{12095} * 306K$

= 76 K

BSE-2 Q_{uE} = 1.5 W

= 1.5 * 76

= 114 K

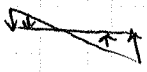
BSE-2 M_{OT} = V * h

= 114 K * 8.67 FT

= 986 K-FT

$\frac{M}{S} = \frac{986}{1.5 * \frac{(13)^2}{6}} * 1.5 = 35$ KLF

BSE-2 $\frac{Q_{uE}}{J} = \frac{35}{2} = 17.5$ KLF FROM START OF FOOTING TO 13 FT



FROM PREVIOUS, (E) FOOTING CAPACITY:

Q_{CL} = 34.3 K-FT

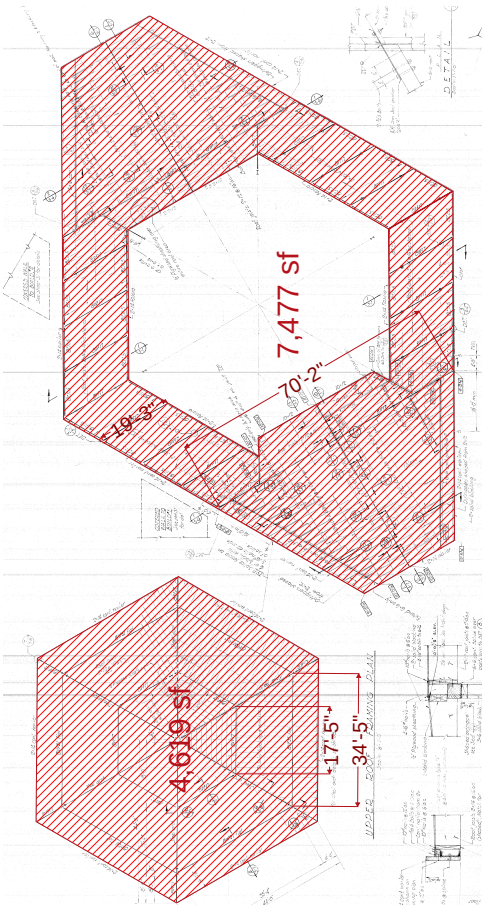
FROM RISA,

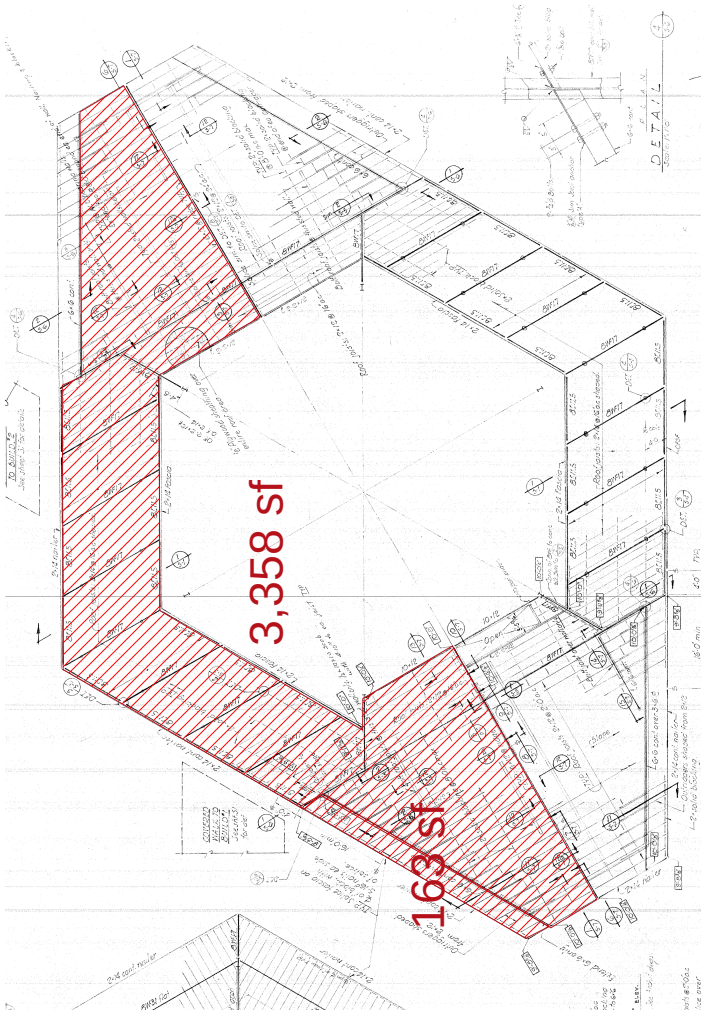
BSE-2 Q_{uE} = 259 K-FT AT 26 FT

-186 K-FT AT 13 FT

BSE-2 $\frac{Q_{uE}}{Q_{CL}} = \frac{259}{34.3} = 7.6$

1959 Multi-Use





Roof Area = 12095 sf *(Includes Overhang)*

Diaphragm: Roof Slope: 3.25:12 Slope Factor: 1.04

Roof Materials	PSF		Diaphragm Wt
Built up roofing	6.0	*x Roof Area =*	75 kips
1/2" Plywood	1.5		19 kips
2x12 Wood Rafters @ 24"oc	2.6		33 kips
Steel Beams	1.4		17 kips
M/E/P	1.5		19 kips
Ceiling	1.5		19 kips
Insulation	1.0		13 kips
Misc.	2.5		31 kips
Total	18.0	Sum =	225 kips

1) Diaphragm weights include the diaphragm and half of the height of out-of-plane walls.

2) Seismic wall weights include half height of wall.

Ext Walls

Line	Elements	PSF	x Length (ft)or Quantity	x Height (ft)	= Wall Weight	Diaphragm Wall Wt
1	8" CMU Wall	80	19	8.7	13 kips	7 kips
	Window	10	0	9.0	kips	kips
				Sum =	13 kips	7 kips
2	8" CMU Wall	80	13	8.7	9 kips	5 kips
	Window	10	28	9.0	3 kips	1 kips
				Sum =	12 kips	6 kips
3	8" CMU Wall	80	0	8.7	kips	kips
	Window	10	40	9.0	4 kips	2 kips
				Sum =	4 kips	2 kips
4	8" CMU Wall	80	25	8.7	17 kips	9 kips
	Window	10	0	9.0	kips	kips
				Sum =	17 kips	9 kips
5	8" CMU Wall	80	0	8.7	kips	kips
	Window	10	40	9.0	4 kips	2 kips
				Sum =	4 kips	2 kips
6	8" CMU Wall	80	24	8.7	17 kips	8 kips
	Window	10	16	9.0	1 kips	1 kips
				Sum =	18 kips	9 kips

Int Walls

Line	Elements	PSF	x	Length (ft)or Quantity	x	Height (ft)	=	Wall Weight	Diaphragm Wall Wt
1	Wood Framed Wall	15		50		9.0		7 kips	3 kips
						Sum =		7 kips	3 kips

Line	Elements	PSF	x	Length (ft)or Quantity	x	Height (ft)	=	Wall Weight	Diaphragm Wall Wt
2	8" CMU Wall	80		12		9.0		9 kips	4 kips
						Sum =		9 kips	4 kips

Line	Elements	PSF	x	Length (ft)or Quantity	x	Height (ft)	=	Wall Weight	Diaphragm Wall Wt
3	Wood Framed Wall	15		210		12.0		38 kips	19 kips
						Sum =		38 kips	19 kips

Line	Elements	PSF	x	Length (ft)or Quantity	x	Height (ft)	=	Wall Weight	Diaphragm Wall Wt
4	8" CMU Wall	80		49		9.0		35 kips	18 kips
						Sum =		35 kips	18 kips

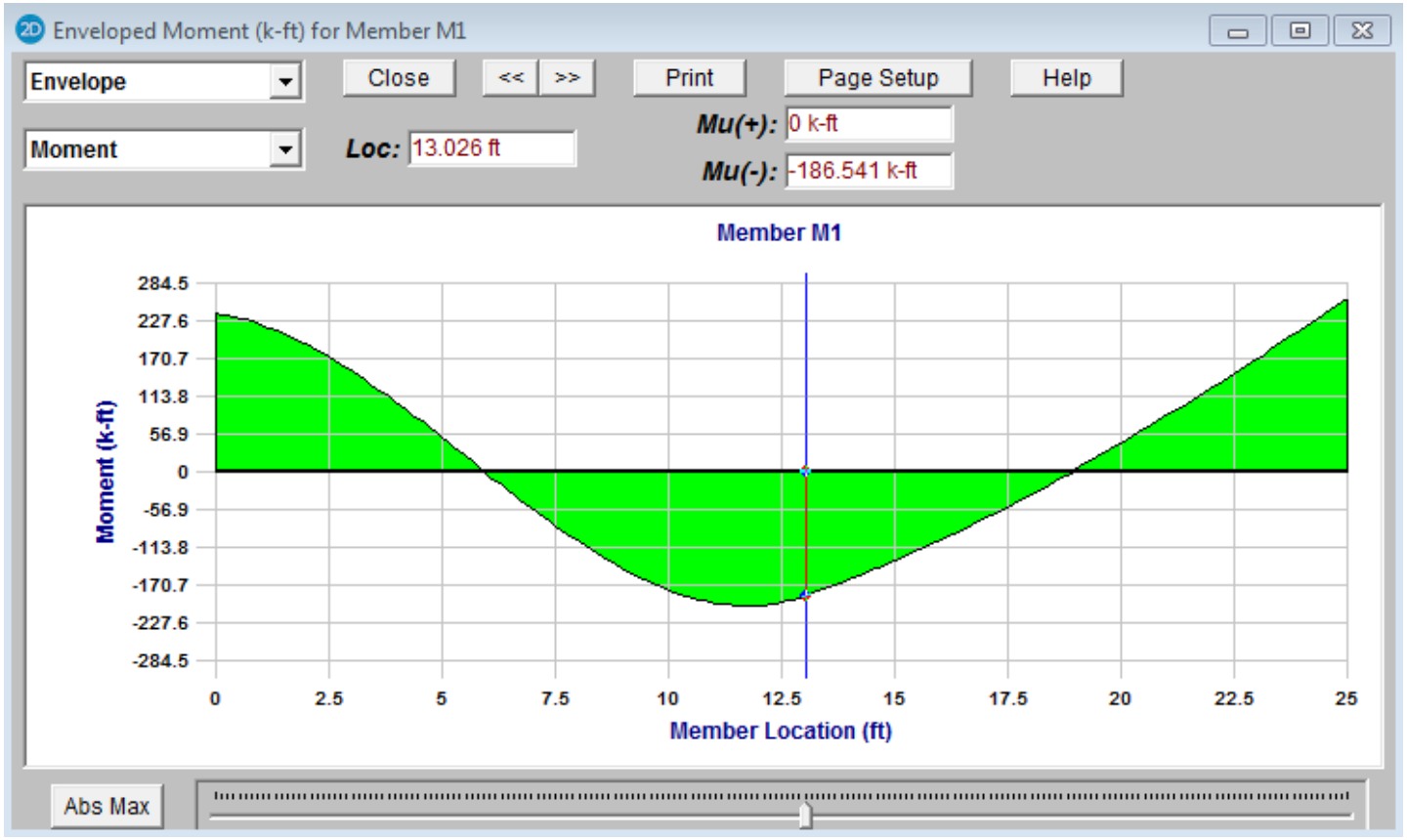
Line	Elements	PSF	x	Length (ft)or Quantity	x	Height (ft)	=	Wall Weight	Diaphragm Wall Wt
5	Wood Framed Wall	15		50		9.0		7 kips	3 kips
						Sum =		7 kips	3 kips

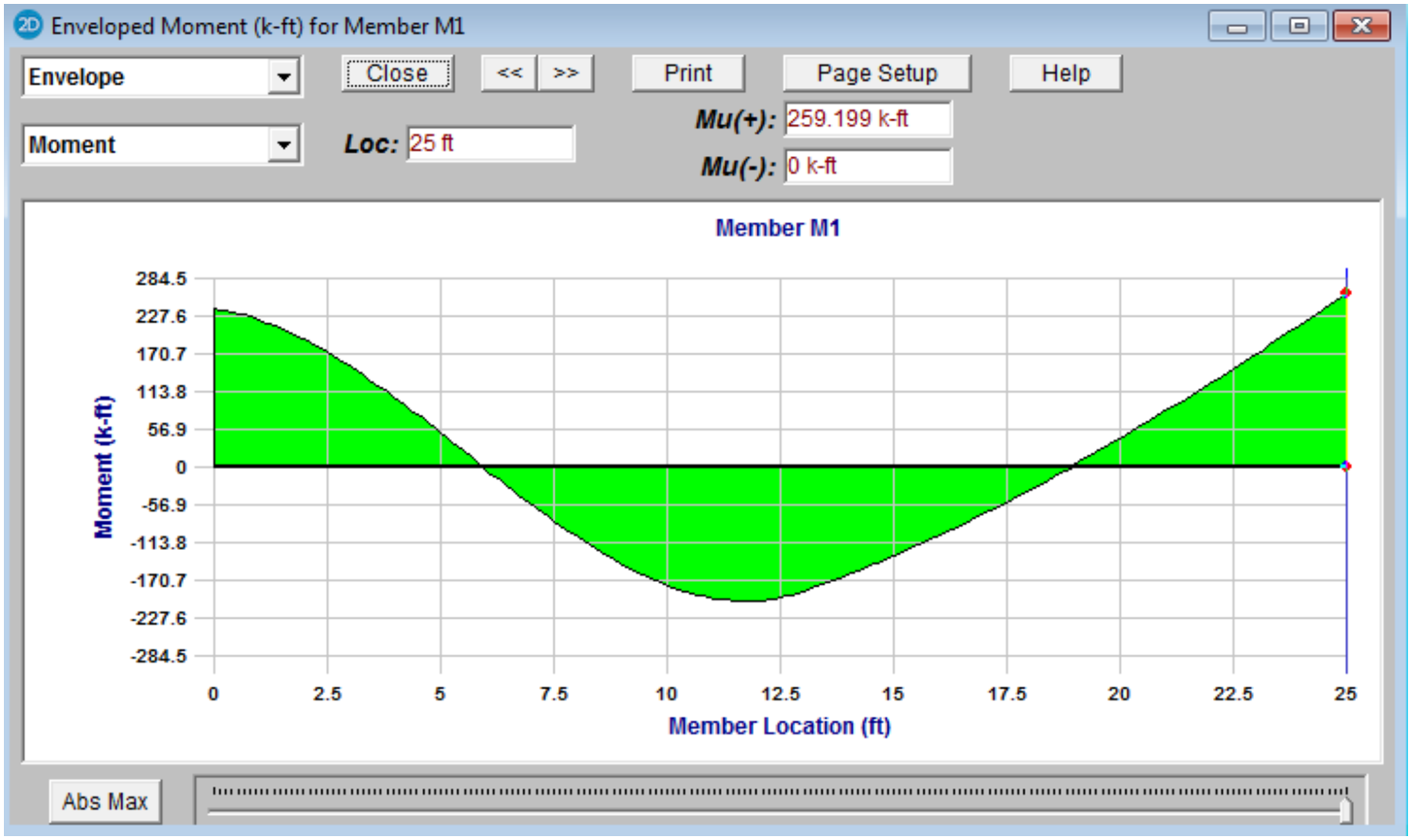
Weight Summary:

Diaphragm Weights

Diaphragm Weight = **306 kips**

1959 Multi-Use





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NEW FOOTING

24" DEEP 36" WIDE (5) # 8 T&B #3 @ 12" o.c.

$$a = \frac{A_s f_y}{0.85 f'_c b}$$

$$= \frac{5 * 0.79 * 60}{0.85 * 3 * 36}$$

$$= 2.58$$

$$\phi M_n = A_s f_y (d - a/2)$$

$$= 5 * 0.79 * 60 \left(20.125 - \frac{2.58}{2}\right)$$

$$= 372 \text{ k-FT}$$

$d = 24" - 3" - 3/8" - \frac{1}{2} * \frac{8}{8}"$

$= 20.125"$

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1974 CLASSROOM

VERTICAL LOADS

INTERIOR WALL - WOOD

WT = 12 PSF

HT = 11.5 FT

WT = 138 PLF

ROOF WEIGHT

WT = 16 PSF

TRIB = $\frac{1}{2}(24 + 28)$

= 26 FT

WT = 416 PLF

FOUNDATION

2'-0" x 2'-0" W1 (2) #5 T&B & #3 @ 16"oc

WT = 2 * 2 * 150

= 600 PLF

SLAB

5" W/ #3 @ 16"oc

WT = 5/12' * 150 PCF

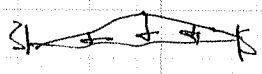
= 63 PSF

MAX WT = 63 PSF * 25 FT

= 1563 PLF

MAX LL = 313 PLF (SEE PREV)

@ MODEL SLAB LOAD AS TRIANGULAR LOAD



LATERAL LOADS

TOTAL SEISMIC WT = 154 K

TOTAL ROOF AREA = 7254 SF

TRIBUTARY ROOF AREA = 1/2(1088 + 1799)

= 1444 SF

TRIBUTARY SEISMIC WEIGHT = $\frac{1444}{7254} * 154$

= 30.6 K

BSE-2 Q_{MF} = 1.5W

= 46 K

B74 CLASSROOM CONT'D

BSE-2 $Q_{uc} = V * L$

$= 46\ K * 11.5\ FT$

$= 529\ K\text{-}FT$

$\frac{M}{S} = \frac{529\ K\text{-}FT}{2 * \frac{25^2}{6}} * 2$

$= 5.1\ KLF$

BSE-2 $\frac{Q_{uc}}{J} = \frac{5.1\ KLF}{2} = 2.5\ KLF$

FOOTING CAPACITY

$f'_{cL} = 2500\ PSI$ $f_{yL} = 40\ KSI$ (PER SHEET S8 OF 16 1974 DWG)

$a = \frac{A_s f_y}{0.85 f'_{cL}}$ $d = 24 - 3 - 3/8 - \frac{1}{2} * \frac{5}{8}$

$= 20.3125$

$= \frac{2 * 0.31 * 40}{0.85 * 2.5 * 24}$

$= 0.49$

$Q_{cL} = A_s f_y (d - a/2)$

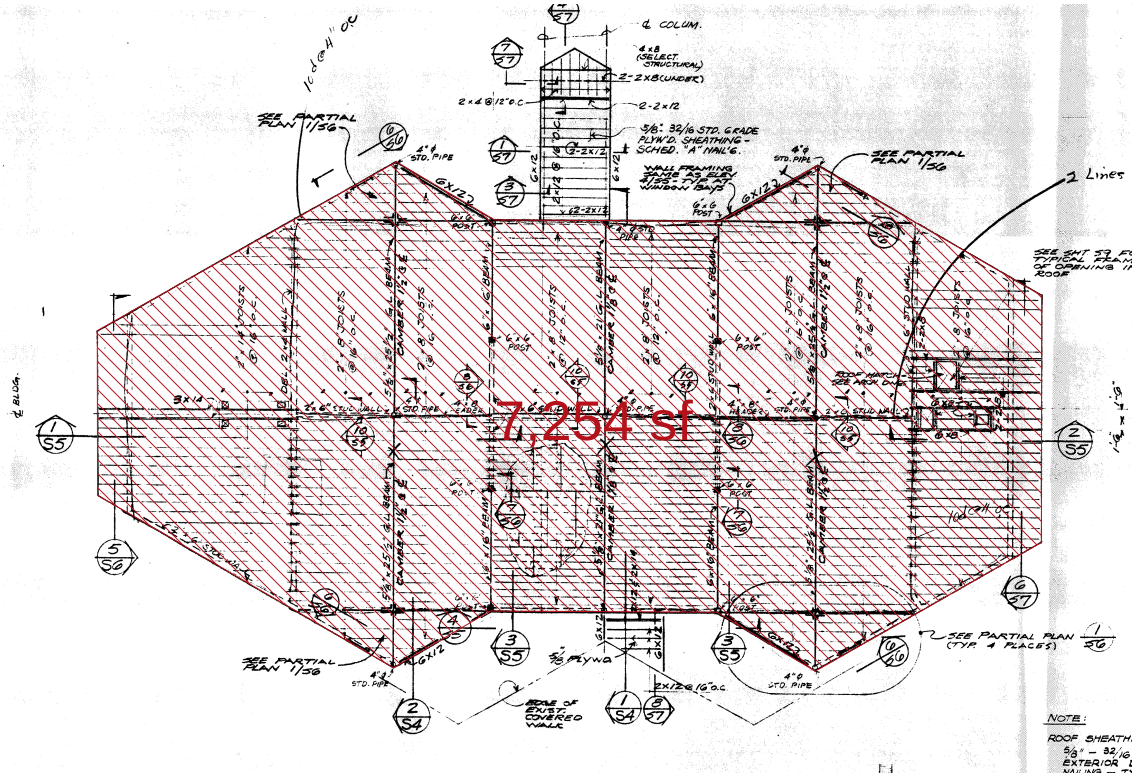
$= 0.31 * 2 * 40 * (20.3125 - \frac{0.49}{2})$

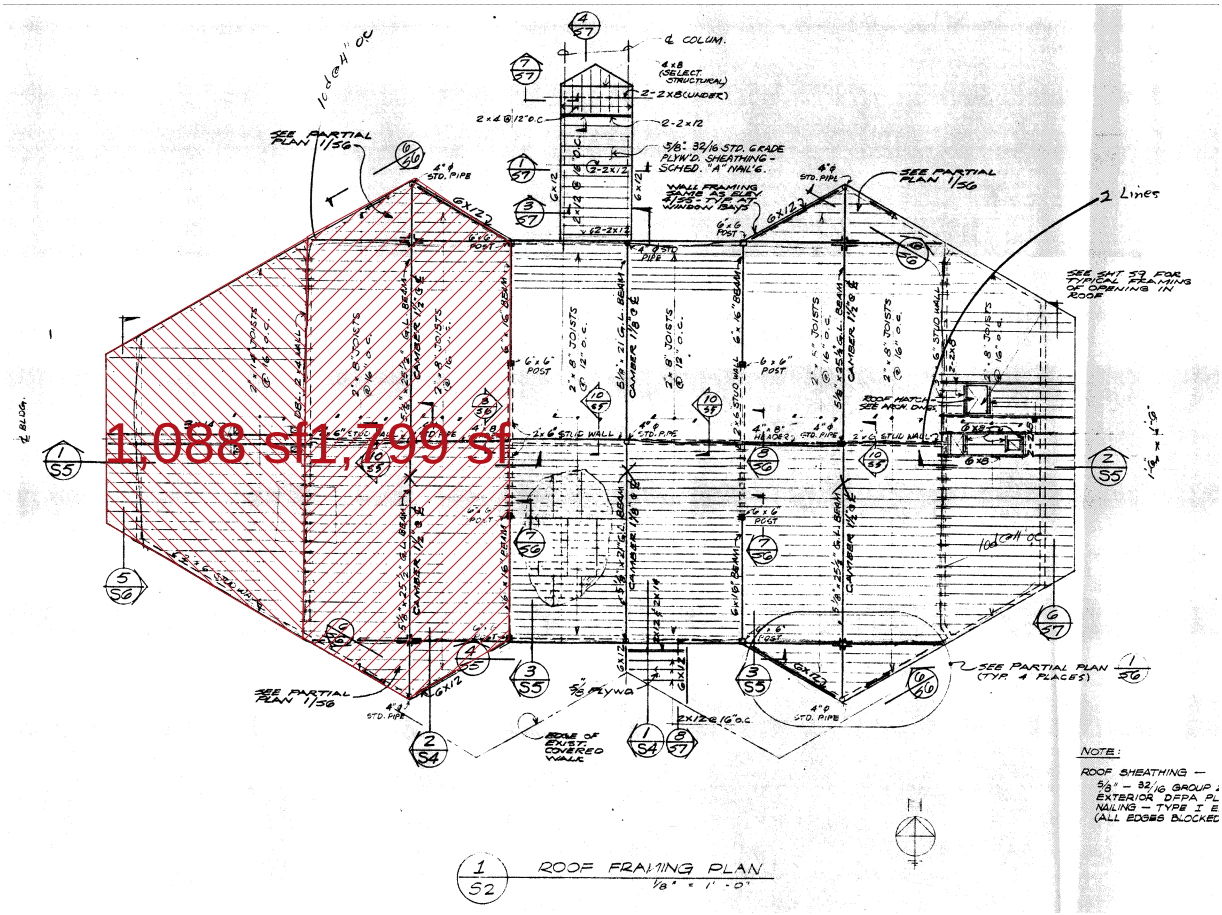
$= 42\ K\text{-}FT$

MAX MOMENT = 159 K-FT

BSE-2 $\frac{Q_{uc}}{Q_{cL}} = \frac{159}{42} = 3.8$

1974 Classroom





Roof Area = **7254 sf** *(Includes Overhang)*

Diaphragm: Roof Slope: 3.25:12 Slope Factor: **1.04**

Roof Materials	PSF		Diaphragm Wt
Built up roofing	6.0	*x Roof Area =*	45 kips
5/8" Plywood	1.5		11 kips
2x8 Wood Rafters @ 16"oc	1.6		12 kips
GLB	0.6		5 kips
M/E/P	1.5		11 kips
Ceiling	1.5		11 kips
Insulation	1.0		8 kips
Misc.	2.3		17 kips
Total	16.0	Sum =	120 kips

1) Diaphragm weights include the diaphragm and half of the height of out-of-plane walls.

2) Seismic wall weights include half height of wall.

Ext Walls

Elements	PSF	x Length (ft)or Quantity	x Height (ft) =	Wall Weight	Diaphragm Wall Wt
Wood Wall	15	315	10.0	47 kips	24 kips
Window	10	35	10.0	4 kips	2 kips
			Sum =	51 kips	25 kips

Int Walls

Elements	PSF	x Length (ft)or Quantity	x Height (ft) =	Wall Weight	Diaphragm Wall Wt
Wood Framed Wall	12	126	11.5	17 kips	9 kips
			Sum =	17 kips	9 kips

Weight Summary:

Diaphragm Weights

Diaphragm Weight = **154 kips**

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