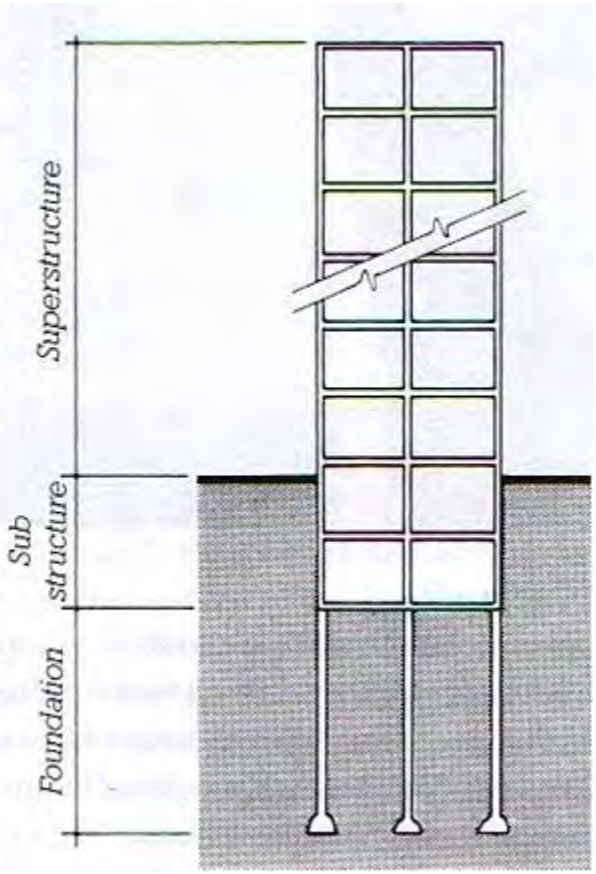
ARCH 2231
BUILDING TECHNOLOGY II

WHITE, JANAE 2019S

Foundations



courtesy of PROF. Jason Montgomery

What makes for a good foundation?

- *It (and underlying soil) must be strong enough to support structure above.*

- *It must not settle enough to damage structure.*

- *It must be feasible, economical to build, & not endanger its neighbors.*

1. <u>Uniform</u>: Equal across foundation

= little or no damage

2. <u>Differential</u>: Columns & Bearing Walls settle

different amounts

= damage or failure.

Most common cause of differential settlement: multiple soil types under building

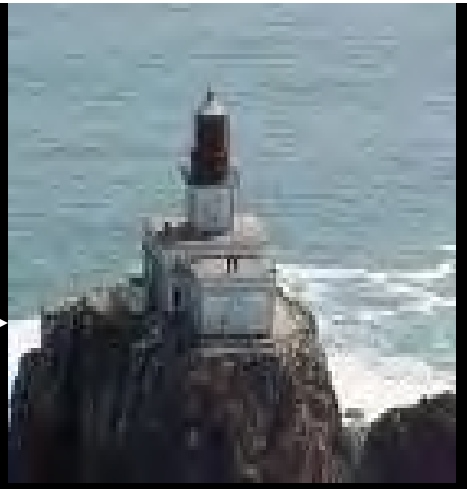
Classifying Earth Materials

- *Rock:* continuous mass of solid mineral material
  - Generally, the strongest, most stable of earth materials
  - Strength varies with mineral content and physical structure

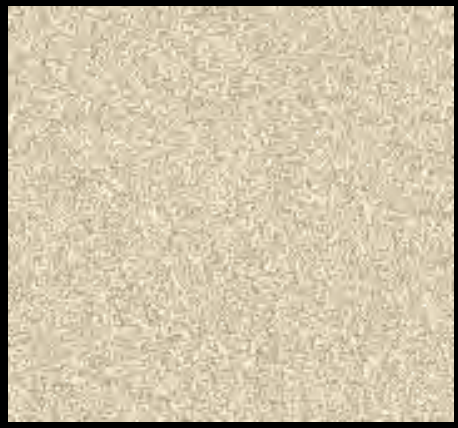
- *Soil:* particulate
  - Small enough to be lifted by hand
  - Characteristics and suitability for foundation support vary with particle size and shape, mineral content, and sensitivity to moisture content

Types of soil by size:

1. *Rock (limestone, granite) Strongest, most stable*



2. *Gravel (half of particles less than 1 / 4 inch*

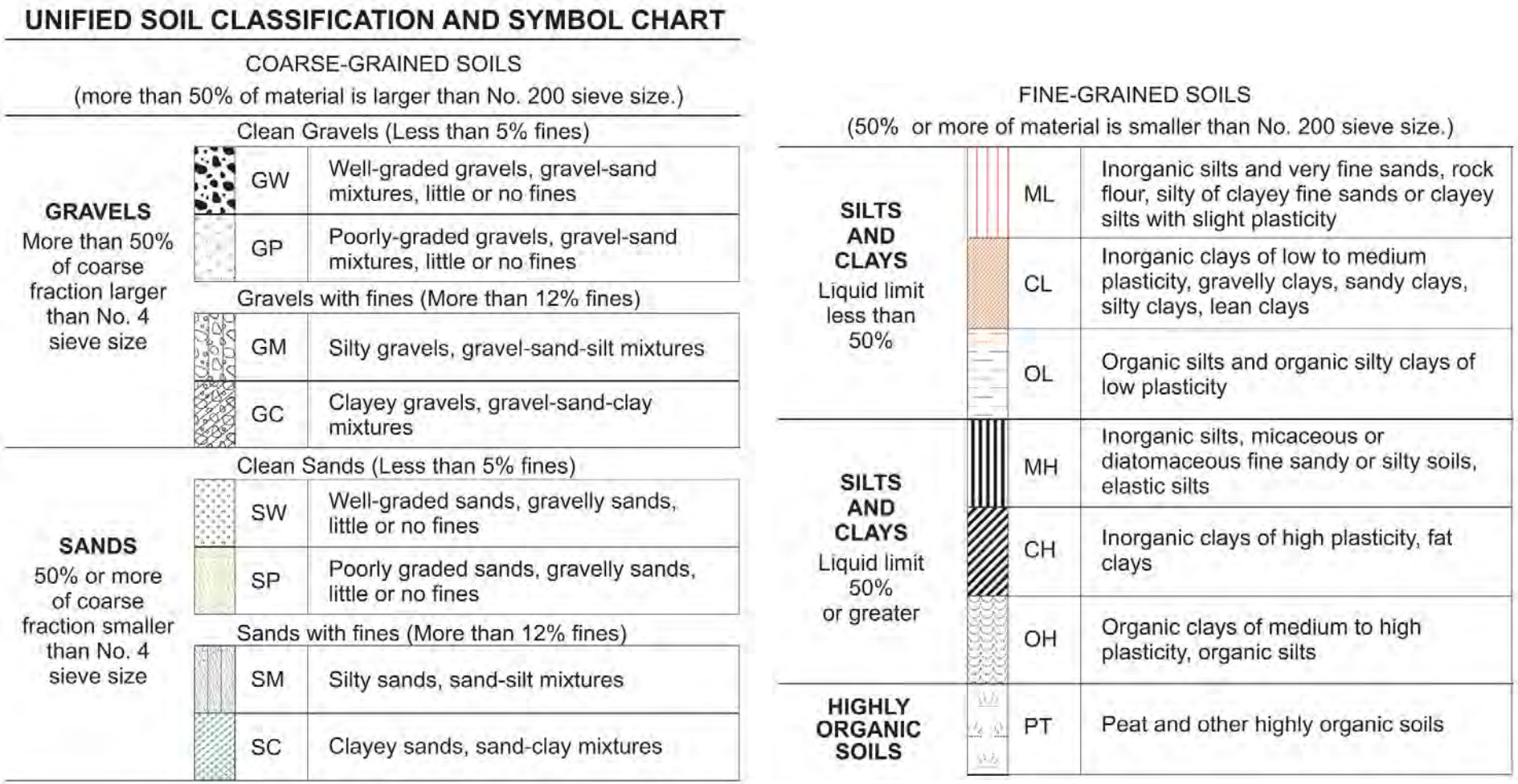


3. *Sand (1 / 4" .002 inch)*

4. *Silt (.002 – .008 inch)*

5. *Clay (less than .008 inch & plate-shaped*

Classifying Earth Materials

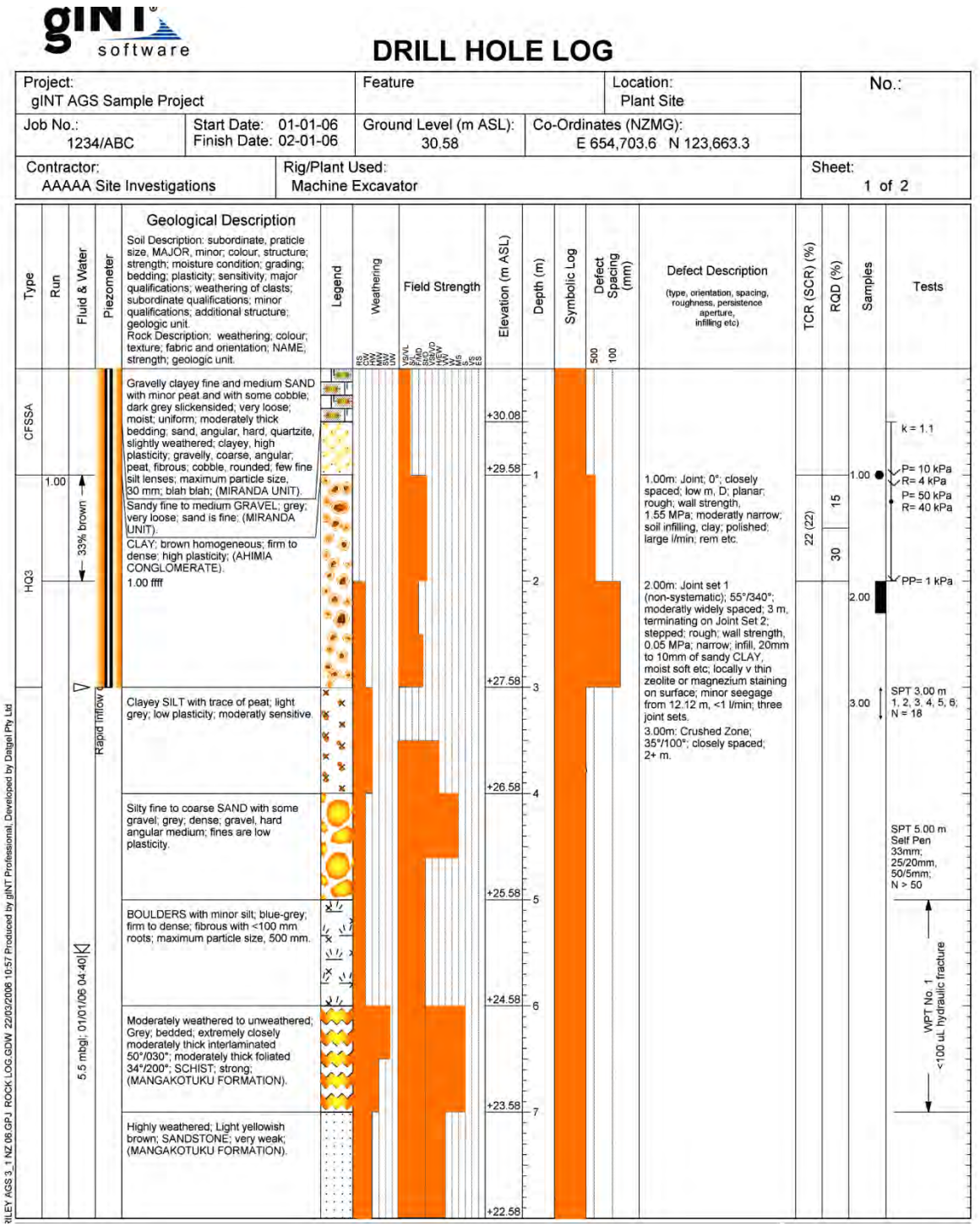


UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)			
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size	Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
	Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
		GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size	Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
		SP	Poorly graded sands, gravelly sands, little or no fines
	Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)			
SILTS AND CLAYS Liquid limit less than 50%		ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		PT	Peat and other highly organic soils

http://matrix.vtrc.virginia.edu/DATA/GINT/vdotusc.PDF

- Boring Report
  - -- soil type
  - -- particle size
  - -- bearing capacity
  - -- water content
  - -- expected settlement



gINT software

DRILL HOLE LOG

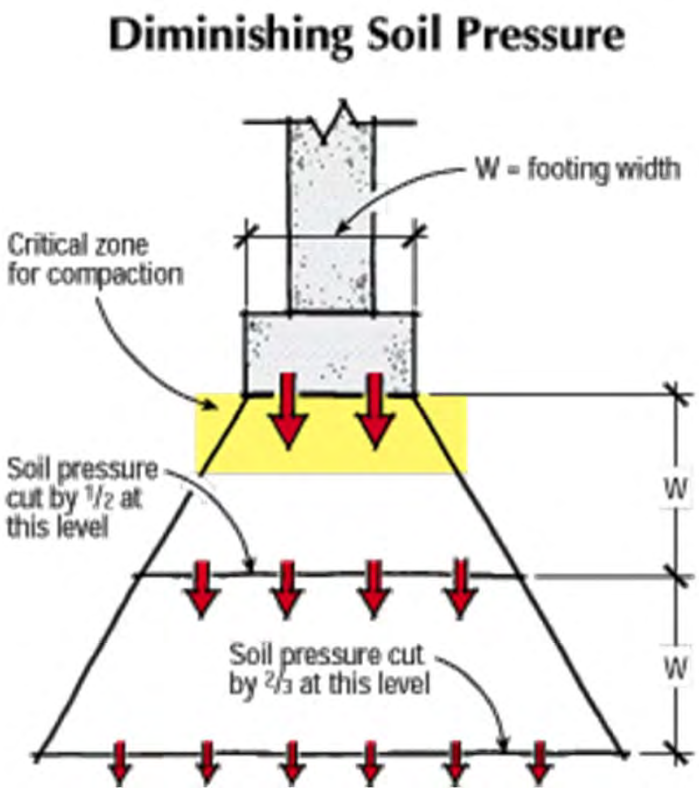
Project: gINT AGS Sample Project	Feature	Location: Plant Site	No.:
Job No.: 1234/ABC	Start Date: 01-01-06 Finish Date: 02-01-06	Ground Level (m ASL): 30.58	Co-Ordinates (NZMG): E 654,703.6 N 123,663.3
Contractor: AAAAA Site Investigations	Rig/Plant Used: Machine Excavator		Sheet: 1 of 2

Type	Run	Fluid & Water	Piezometer	Geological Description	Legend	Weathering	Field Strength	Elevation (m ASL)	Depth (m)	Symbolic Log	Defect Spacing (mm)	Defect Description (type, orientation, spacing, roughness, persistence aperture, infilling etc)	TCR (SCR) (%)	RQD (%)	Samples	Tests
CFSSA				Soil Description: subordinate, praticle size, MAJOR, minor; colour, structure; strength; moisture condition; grading; bedding; plasticity; sensitivity; major qualifications; weathering of clasts; subordinate qualifications; minor qualifications; additional structure; geologic unit. Rock Description: weathering; colour; texture; fabric and orientation; NAME; strength; geologic unit.		RS CW MW SW VSWL SWD SWD MSWD MW SW WS VS ES		+30.08			500 100					
HQ3	1.00	33% brown	Rapid Inflow	Gravelly clayey fine and medium SAND with minor peat and with some cobble; dark grey slickensided; very loose; moist; uniform; moderately thick bedding; sand, angular, hard, quartzite, slightly weathered; clayey, high plasticity; gravelly, coarse, angular; peat, fibrous; cobble, rounded, few fine silt lenses; maximum particle size, 30 mm; blah blah; (MIRANDA UNIT).				+29.58	1			1.00m: Joint; 0°; closely spaced; low m, D; planar; rough; wall strength, 1.55 MPa; moderatly narrow; soil infilling, clay; polished; large l/min; rem etc.	22 (22)	15	1.00	k = 1.1 P= 10 kPa R= 4 kPa P= 50 kPa R= 40 kPa
				Sandy fine to medium GRAVEL; grey; very loose; sand is fine; (MIRANDA UNIT).										30		
				CLAY; brown homogeneous; firm to dense; high plasticity; (AHIMIA CONGLOMERATE). 1.00 ffff					2			2.00m: Joint set 1 (non-systematic); 55°/340°; moderatly widely spaced; 3 m, terminating on Joint Set 2; stepped; rough; wall strength, 0.05 MPa; narrow; infill, 20mm to 10mm of sandy CLAY, moist soft etc; locally v thin zeolite or magnezium staining on surface; minor seegage from 12.12 m, <1 l/min; three joint sets.			2.00	PP= 1 kPa
				Clayey SILT with trace of peat; light grey; low plasticity; moderatly sensitive.				+27.58	3			3.00m: Crushed Zone; 35°/100°; closely spaced; 2+ m.			3.00	SPT 3.00 m 1, 2, 3, 4, 5, 6; N = 18
				Silty fine to coarse SAND with some gravel; grey; dense; gravel, hard angular medium; fines are low plasticity.				+26.58	4							
				BOULDERS with minor silt; blue-grey; firm to dense; fibrous with <100 mm roots; maximum particle size, 500 mm.				+25.58	5							SPT 5.00 m Self Pen 33mm; 25/20mm, 50/5mm; N > 50
				Moderately weathered to unweathered; Grey; bedded; extremely closely moderately thick interlaminated 50°/030°; moderately thick foliated 34°/200°; SCHIST; strong; (MANGAKOTUKU FORMATION).				+24.58	6							
				Highly weathered; Light yellowish brown; SANDSTONE; very weak; (MANGAKOTUKU FORMATION).				+23.58	7							WPT No. 1 <100 uL hydraulic fracture
								+22.58								

5.5 mbgl; 01/01/06 04:40

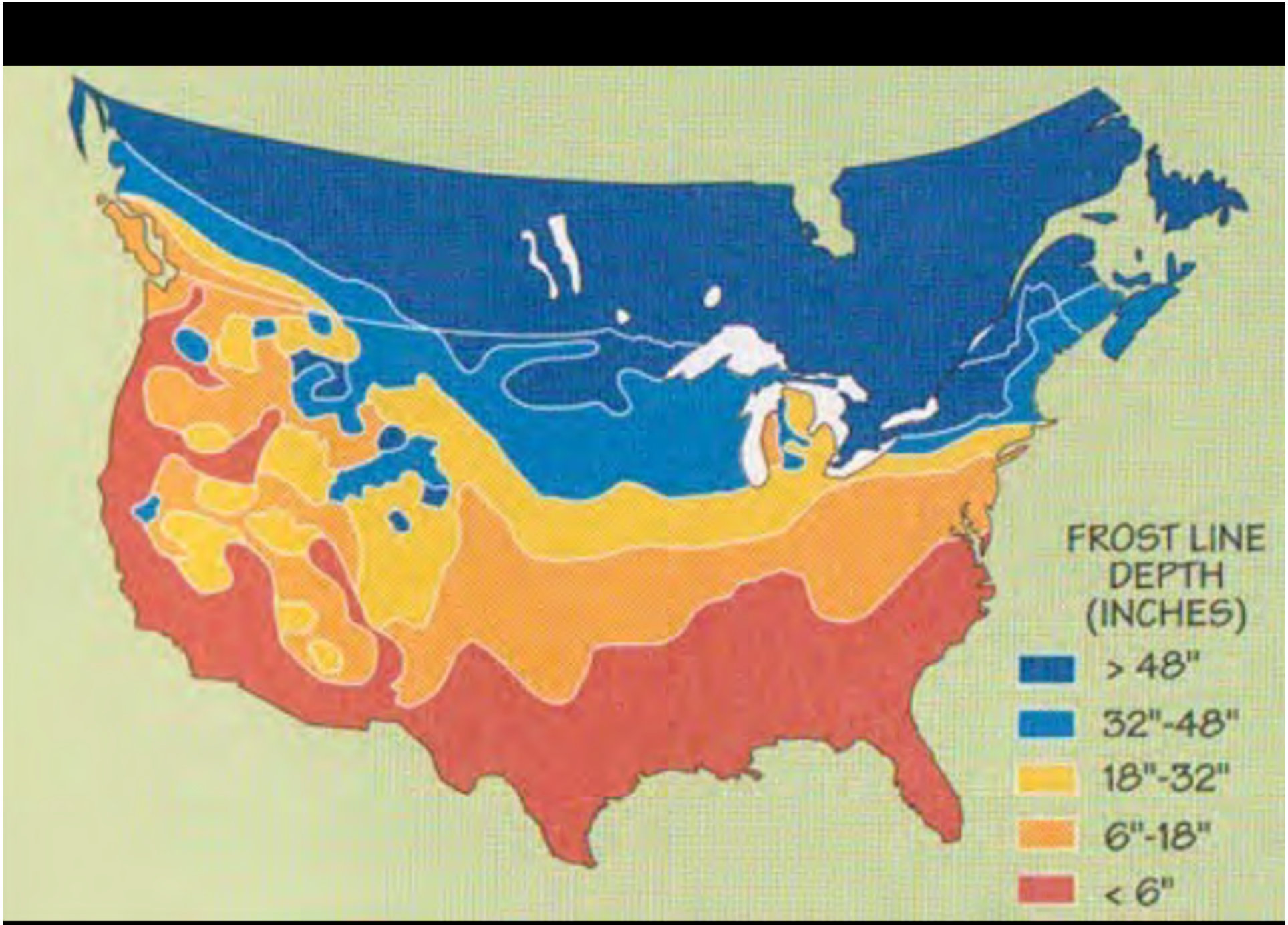
RLEY AGS 3_1 NZ 06.GPJ ROCK LOG.GDW 22/03/2006 10:57 Produced by gINT Professional, Developed by Daigel Pty Ltd

http://www.gintsoftware.com/reports_boringlogs.html



Soil Bearing Capacities	
Class of Materials	**Load-Bearing Pressure (pounds per square foot)**
Crystalline bedrock	12,000
Sedimentary rock	6,000
Sandy gravel or gravel	5,000
Sand, silty sand, clayey sand, silty gravel, and clayey gravel	3,000
Clay, sandy clay, silty clay, and clayey silt	2,000
Source: Table 401.4.1; CABO One- and Two- Family Dwelling Code; 1995.	

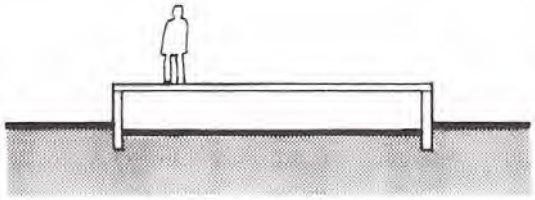
https://pro.homeadvisor.com/article.show.Footing-Fundamentals.13700.html



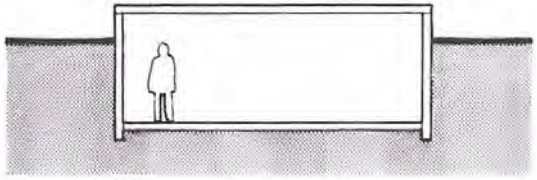
http://discountlowvoltage.blogspot.com/2012/12/whats-my-frost-depth-line-for-osp.html

Shallow Foundations

SLAB ON GRADE



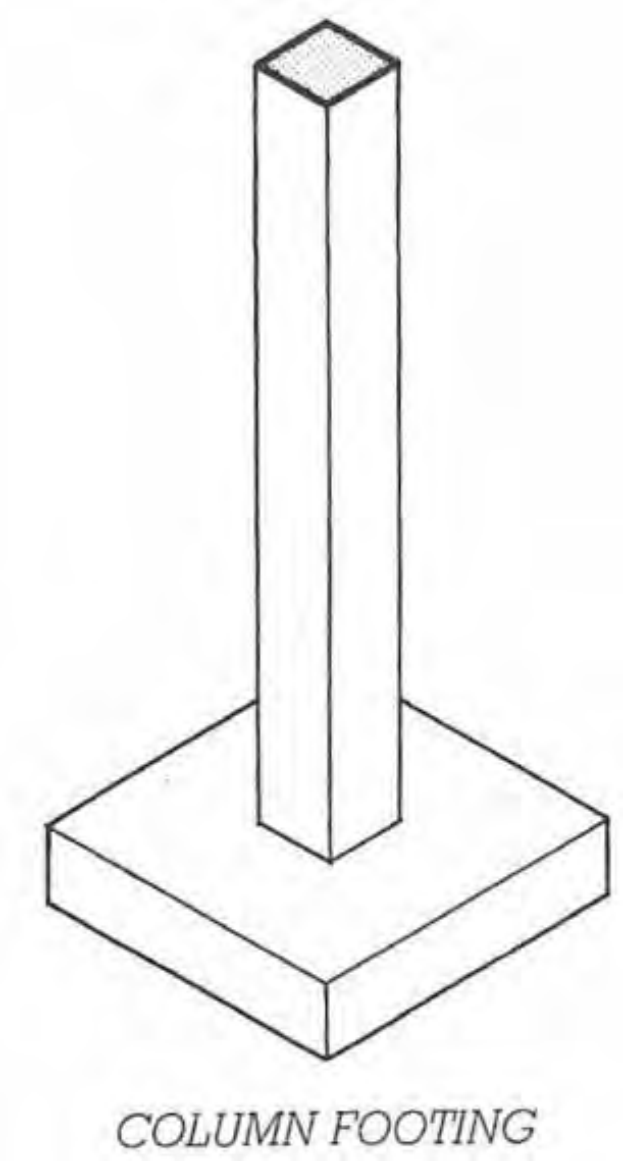
CRAWLSPACE



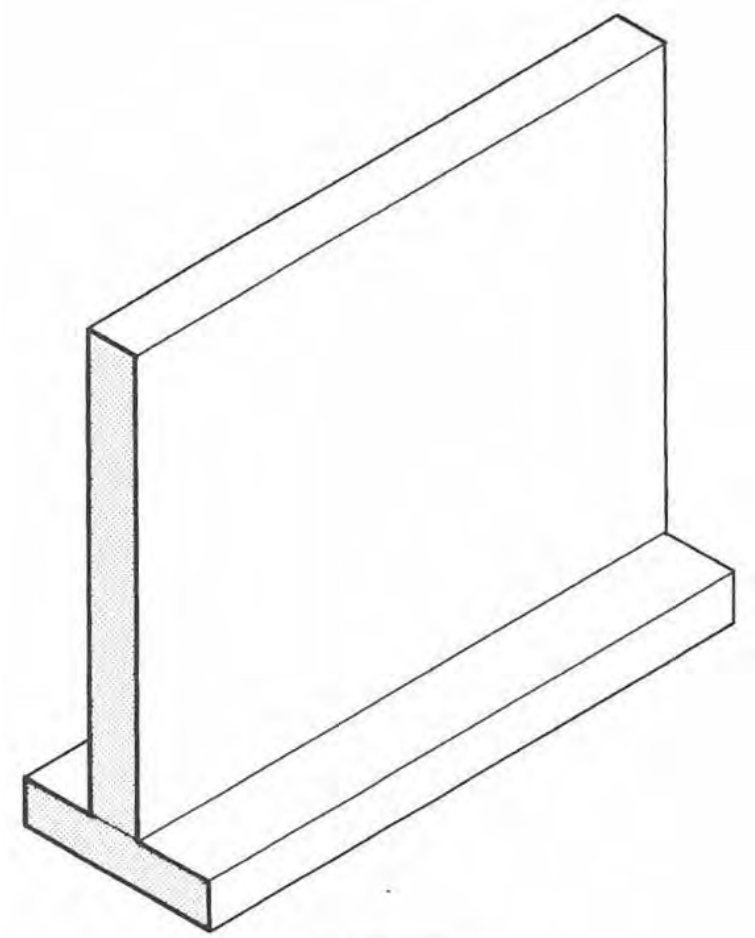
BASEMENT

courtesy of PROF. Jason Montgomery

COLUMN FOOTING



WALL FOOTING (STRIP FOOTING)



WALL FOOTING

courtesy of PROF. Jason Montgomery

Deep Foundations

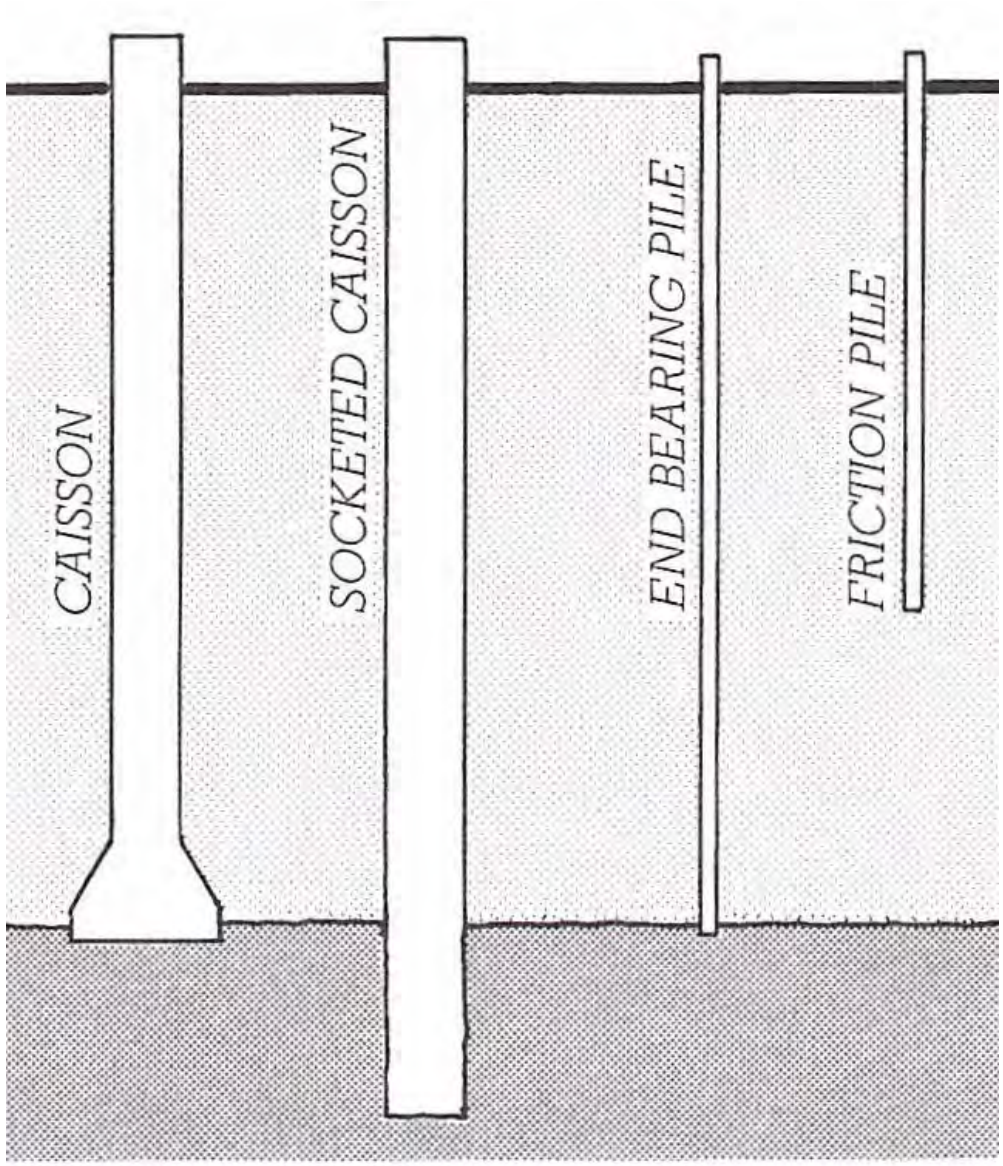
DEEP FOUNDATIONS:

TRANSMIT BUILDING LOADS TO DEEPER, MORE COMPETENT SOILS

THE TWO TYPES OF DEEP FOUNDATIONS ARE:

1. END BEARING
2. BEARING THROUGH FRICTION

NOTE: SOME DEEP FOUNDATIONS FUNCTION IN BOTH MODES.

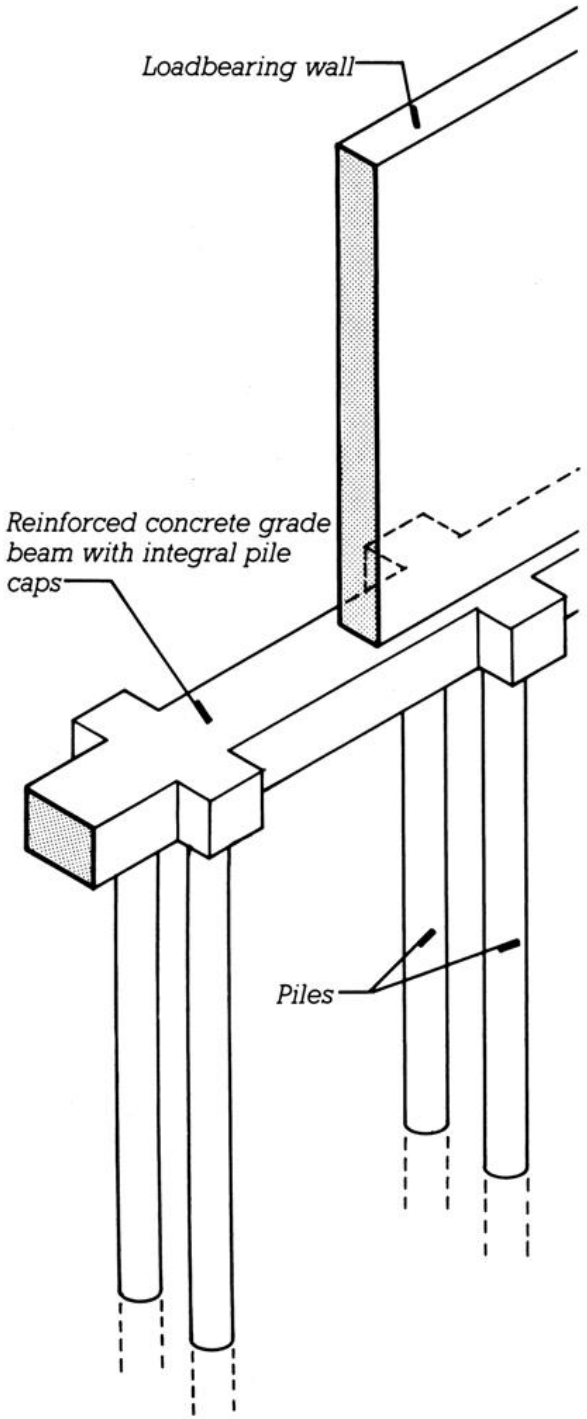


"Fundamentals of Building Construction / Materials and Methods" Allen & Wiley

Piles and Grade Beams

Pile caps share loads among clustered piles.

A *grade beam* spans between the piles to provide continuous support for the wall above.



STEEL CASINGS MAY BE USED TO TEMPORARILY SUPPORT THE SIDE WALLS OF THE HOLE.

REINFORCEMENT IS USUALLY ONLY REQUIRED AT THE TOP TO TIE THE CAISSON TO THE STRUCTURE IT SUPPORTS

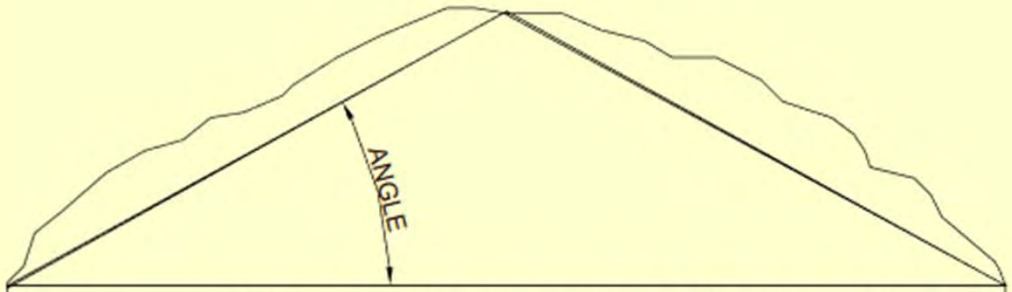
Foundation design

http://www.homeselfe.com/wp-content/uploads/2016/02/types-of-foundation0.jpg

Snow Loads

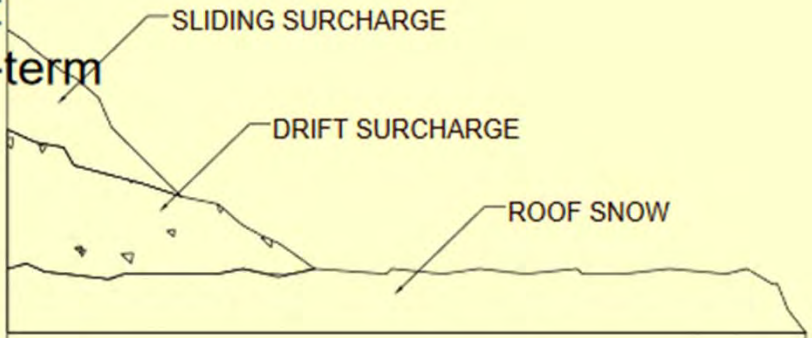
https://www.edtengineers.com/sites/default/files/2019-02/GettyImages-182865717.jpg

Snow Loads



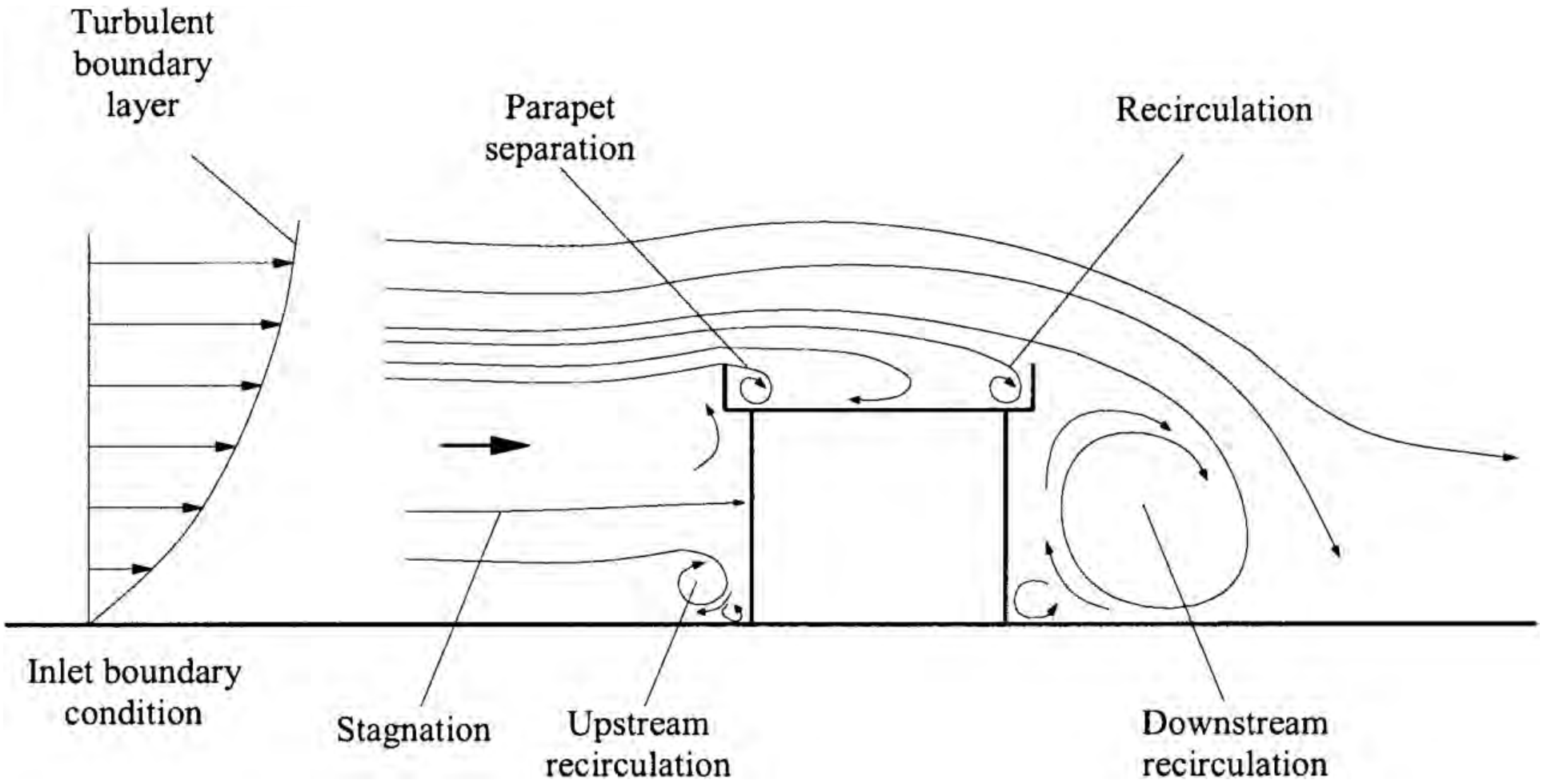
Note a 15% increase in the allowable capacity of wood for loads that include snow, which is a short-term load

Slope	C_s
7/12	0.99
8/12	0.91
9/12	0.83
10/12	0.75
11/12	0.69
12/12	0.63



Note that roofs exceeding an angle of 30 degrees may reduce the ground snow load.

Wind Loads



https://www.semanticscholar.org/paper/Comprehensive-study-of-wind-loads-on-parapets-Bedair/e8a5397bfb464c3224e5fedff318bb2948813812/figure/5

Soil and Surchare

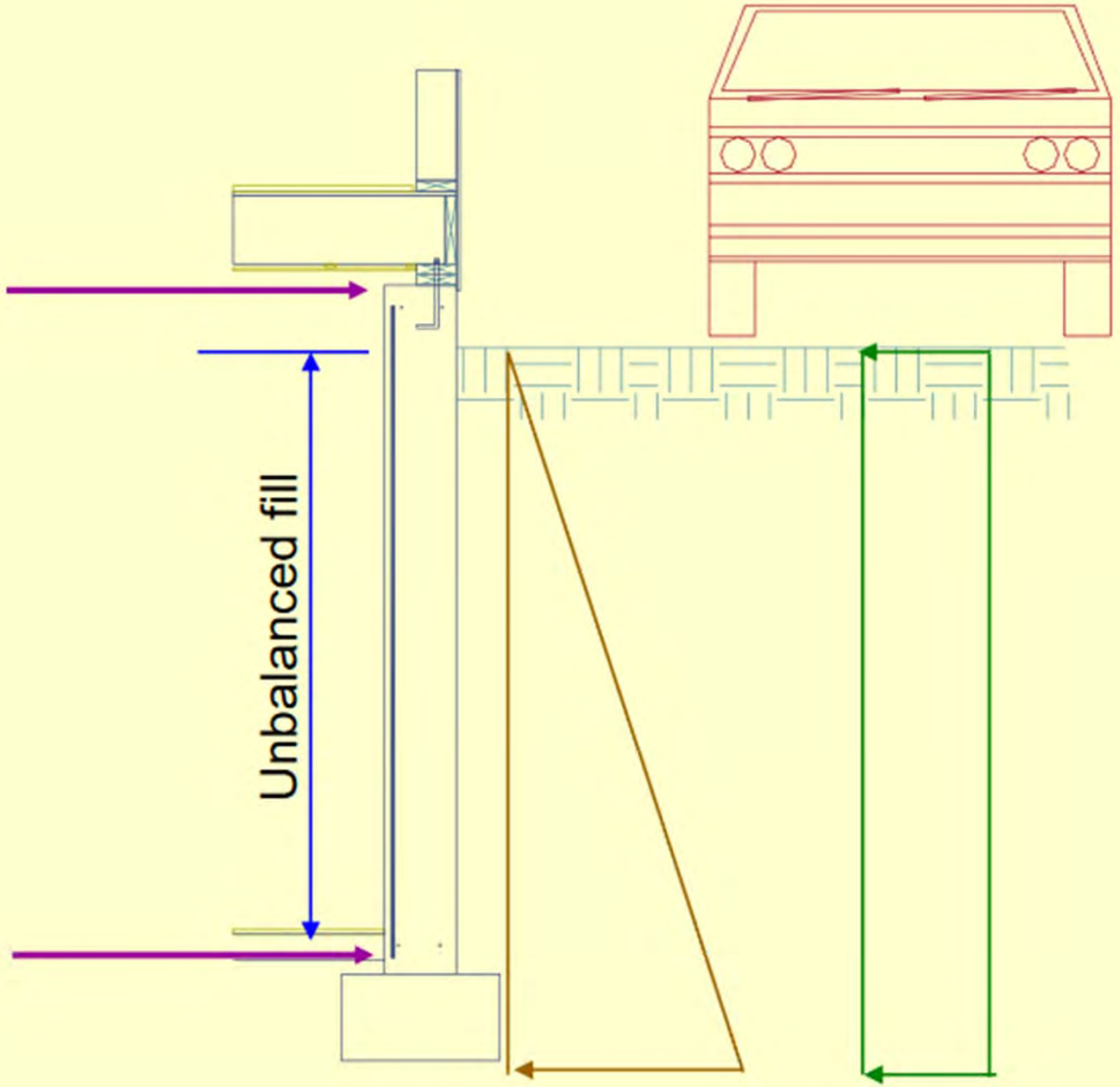


TABLE 3.0a
TYPICAL DEAD LOADS FOR COMMON
RESIDENTIAL CONSTRUCTIONS

Roof Construction			
Light wood or steel framing (trusses), sheathing & gypsum board ceiling, with:			
- asphalt shingles, metal roofing, or wood shakes or shingles			15 psf
- built-up roll roofing, tar and gravel			18 psf
- light weight tile or 1/4" slate			20 psf
- conventional clay tile, concrete tile, or 3/8" slate			25 psf
Floor Construction			
Light wood or steel framing, wood sheathing & gypsum board ceiling, with:			
- carpet or vinyl flooring			10 psf
- wood flooring			12 psf
- ceramic tile & thin-set or dry-set mortar			15 psf
- 1/2"slate or ceramic tile with 1/2" mortar bed			20 psf
Light-Frame Wall Construction			
Light wood or steel framing, wood sheathing, & gypsum board interior finish, with:			
- vinyl or aluminum siding			8 psf
- lap wood siding			9 psf
- thin coat stucco on insulation board			11 psf
- 7/8" portland cement stucco			17 psf
- standard brick veneer			45 psf
Interior partitions (2x4 at 16" o.c. with 1/2" gypsum board applied to both sides)			6 psf
Concrete or Masonry Wall Construction	Masonry (light-weight block)		Concrete
	Hollow	Solid or Full Grout	
4" thick wall	22 psf	--	48 psf
6" thick wall	24 psf	55 psf	72 psf
8" thick wall	31 psf	75 psf	96 psf
10" thick wall	37 psf	95 psf	120 psf
12" thick wall	43 psf	115 psf	144 psf

LIVE LOADS

[THE MASSACHUSETTS STATE BUILDING CODE]

OCCUPANCY OR USE	UNIFORM (psf)	CONCEN-TRATED (lbs.)
5. Balconies (exterior)	100	
On one- and two-family residencesonly, and not exceeding 100 ft.[2]	60	
6. Decks	Same as occupancy served	
7. Bowling alleys	75	
8. Cornices	60	See 780 CMR 1607.11.2.5
9. Corridors, except as otherwise indicated	100	
10. Dance halls and ballrooms	100	
11. Dining rooms and restaurants	100	
12. Dwellings (see residential)		
13. Elevator machine room grating (on area of 4 in.[2])		300
14. Finish light floor plate construction (on area of 1 in.[2])		200
15. Fire escapes	100	
On single-family dwellings only	40	
16. Garages (passenger vehicles only)	50	Note a
Trucks and buses	See 780 CMR 1607.6	
17. Grandstands (see stadium and arena bleachers)		
18. Gymnasiums, main floors and balconies	100	
19. Handrails, guards and grab bars	See 780 CMR 1607.7	
20. Hospitals		
Operating rooms, laboratories	100	1,000
Private rooms	40	1,000
Wards	40	1,000
Corridors above first floor	80	1,000
21. Hotels (see residential)		
22. Laboratories	100	2,000
23. Libraries		
Reading rooms	60	1,000
Stack rooms	150[b]	1,000
Corridors above first floor	80	1,000
24. Manufacturing		
Light	125	2,000
Heavy	250	3,000
25. Marquees	75	
26. Office buildings		
File and computer rooms shall be designed for heavier loads based on anticipated occupancy		
Lobbies and first-floor corridors	100	2,000
Offices	50	2,000
Corridors above first floor	80	2,000
27. Penal institutions		
Cell blocks	40	
Corridors	100	
29. Reviewing stands, grandstands and bleachers	Note c	
30. Roofs	See 780 CMR 1607.11	
31. Schools		
Classrooms	50	1,000
Corridors above first floor	80	1,000
First-floor corridors	100	1,000
32. Scuttles, skylight ribs and accessible ceilings		200
33. Sidewalks, vehicular driveways and yards, subject to trucking	250[d]	8,000[e]
34. Skating rinks	100	
35. Stadiums and arenas		
Bleachers	100[c]	
Fixed seats (fastened to floor)	60[c]	
36. Stairs and exits	100	
One- and two-family dwellings	40	Note f
All other	100	
37. Storage warehouses (shall be designed for heavier loads if required for anticipated storage)		
Light	125	
Heavy	250	
38. Stores		
Retail		
First floor	100	1,000
Upper floors	75	1,000
Wholesale, all floors	125	1,000
39. Vehicle barriers	See 780 CMR 1607.7	
40. Walkways and elevated platforms (other than exitways)	60	
41. Yards and terraces, pedestrians	100	

https://www.mass.gov/files/documents/2016/09/vi/780016.pdf

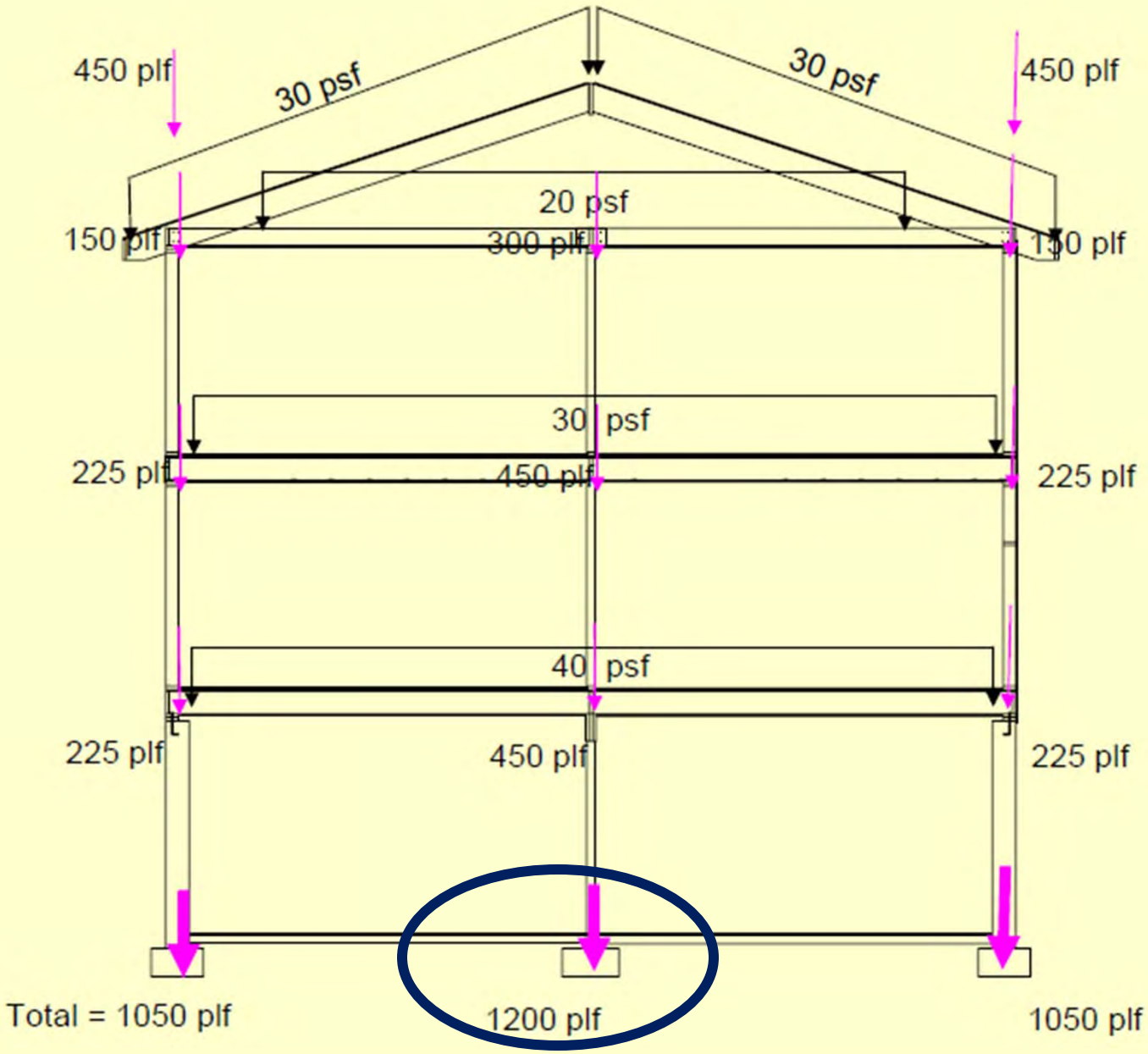
LIVE LOADS

[THE MASSACHUSETTS STATE BUILDING CODE]

OCCUPANCY OR USE	UNIFORM (psf)	CONCEN-TRATED (lbs.)
28. Residential		
Group R-3		
Uninhabitable attics without storage	10	
Uninhabitable attics with storage	20	
Habitable attics and sleeping areas	30	
All other areas except balconies and decks	40	
Hotels and multifamily dwellings		
Corridors above first floor serving guest rooms	80	
Private rooms	40	
Public rooms and corridors serving them	100	

https://www.mass.gov/files/documents/2016/09/vi/780016.pdf

Follow the load path due to gravity Diagram



Forces flow diagram

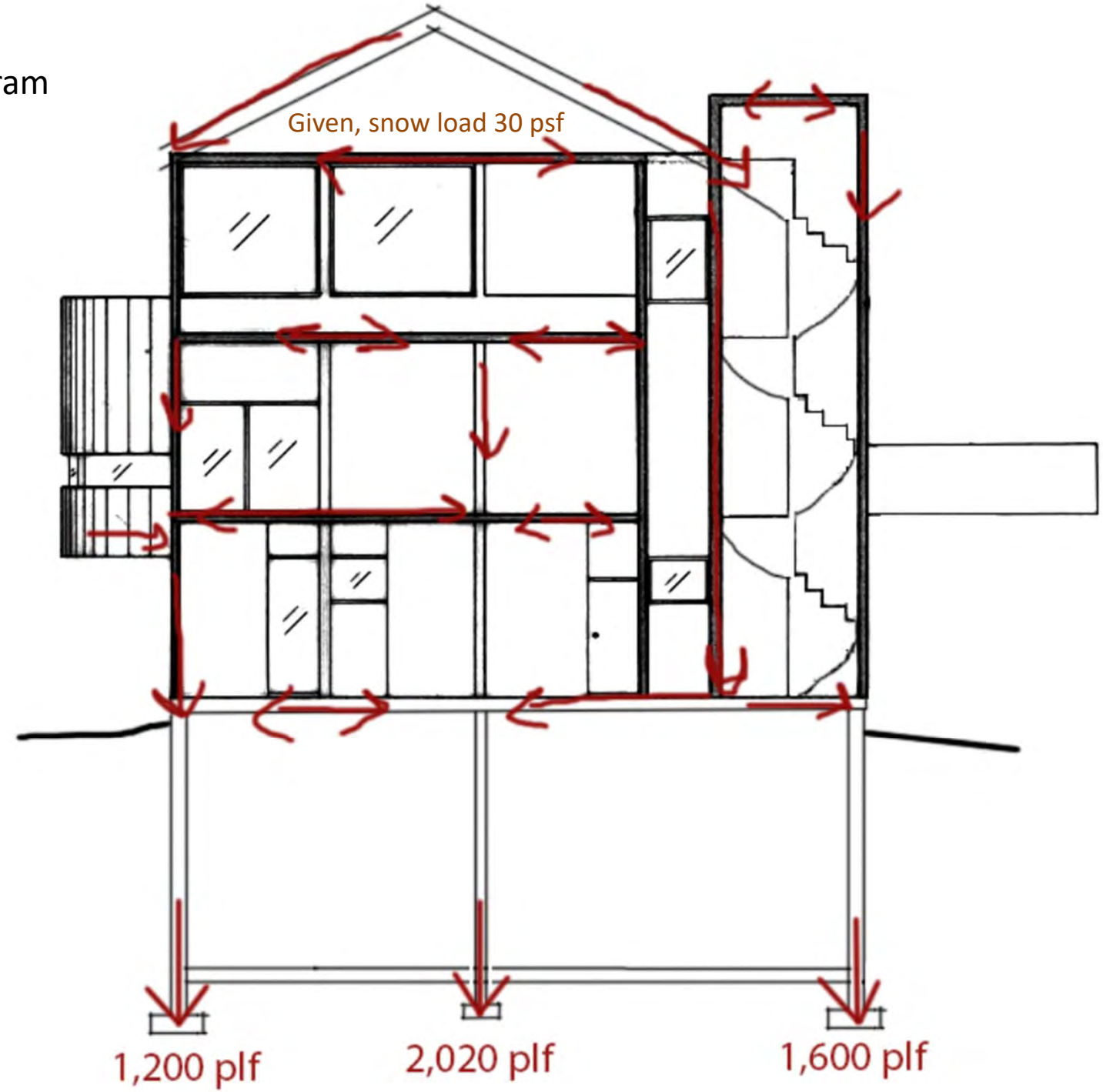


TABLE R401.4.1 PRESUMPTIVE LOAD-BEARING VALUES OF FOUNDATION MATERIALS[a]

CLASS OF MATERIAL	LOAD-BEARING PRESSURE (pounds per square foot)
Crystalline bedrock	12,000
Sedimentary and foliated rock	4,000
Sandy gravel and/or gravel (GW and GP)	3,000
Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC)	2,000
Clay, sandy, silty clay, clayey silt, silt and sandy siltclay (CL, ML, MH and CH)	1,500[b]

For SI: 1 pound per square foot = 0.0479 kPa.

a. Where soil tests are required by Section R401.4, the allowable bearing capacities of the soil shall be part of the recommendations.

b. Where the building official determines that in-place soils with an allowable bearing capacity of less than 1,500 psf are likely to be present at the site, the allowable bearing capacity shall be determined by a soils investigation.

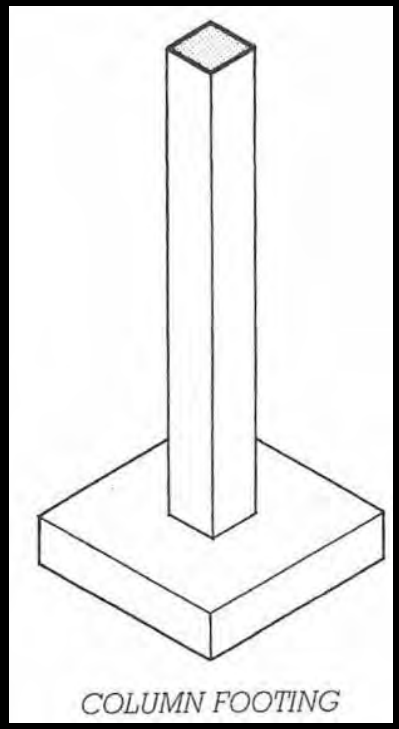
Residential Code 2015 of Massachusetts https://up.codes/viewer/massachusetts/irc-2015/chapter/4/foundations#table_R401.4.1

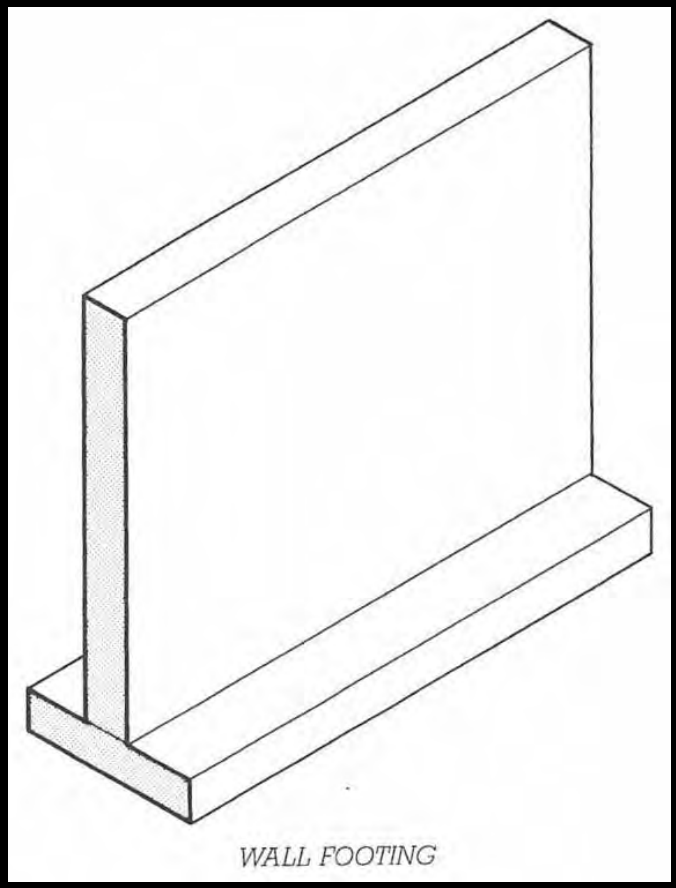
Borings Soil Report			
Soil type:	**Depth range**		
Sedimentary rock	18'-1"	to	20'
Sandy gravel	10'-1"	to	18'
Sand	6'-1"	to	10'
Sedimentary rock	5'-1"	to	6'
Sandy clay	4'-1"	to	5'
Sandy gravel	2'-1"	to	4'
Topsoil	0'	to	2'

https://www.teds-fl.com/images/civil-engineering-pic6.jpg

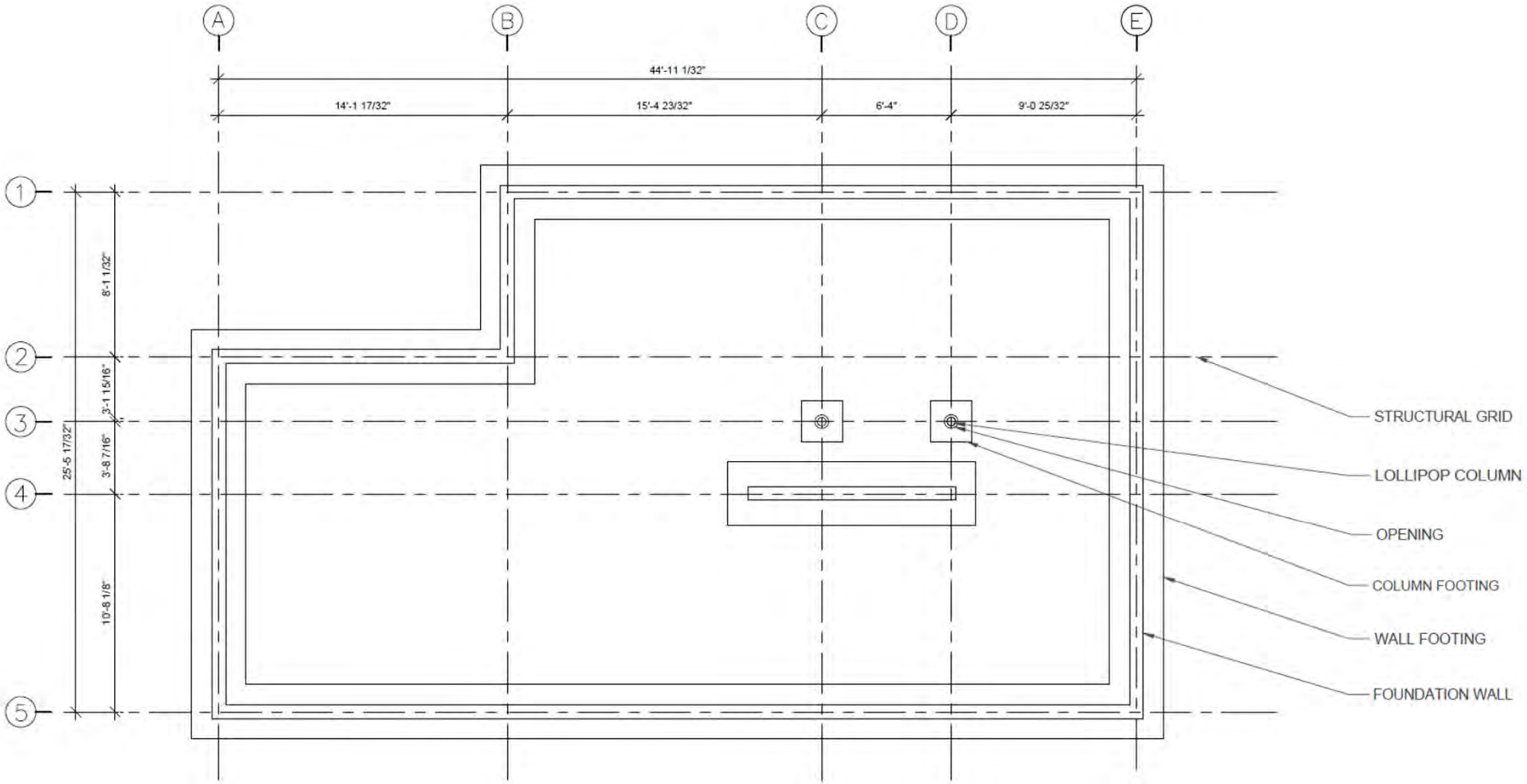
Foundation design

Design your project cellar to have perimeter foundation footing wall and at least one column with column footing.

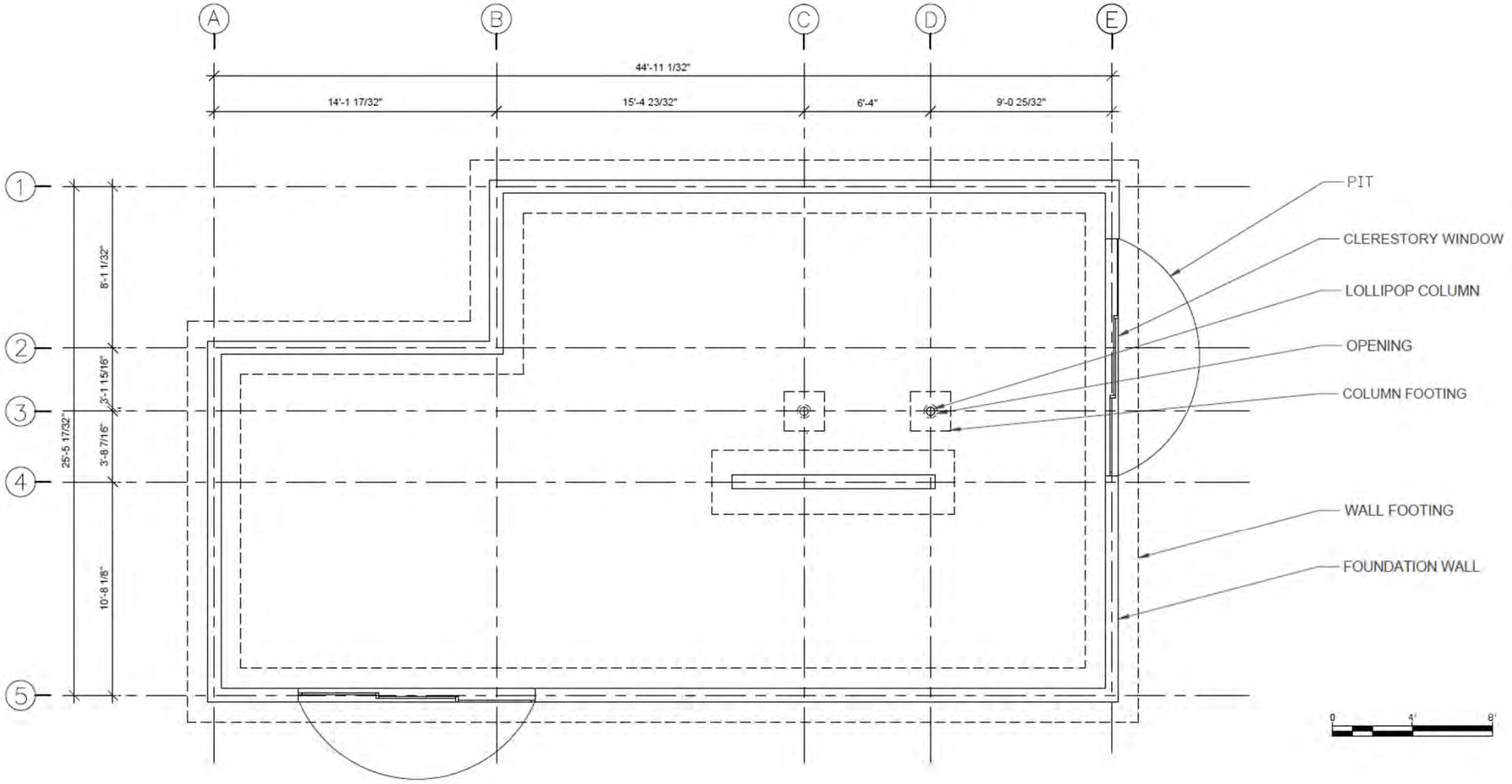


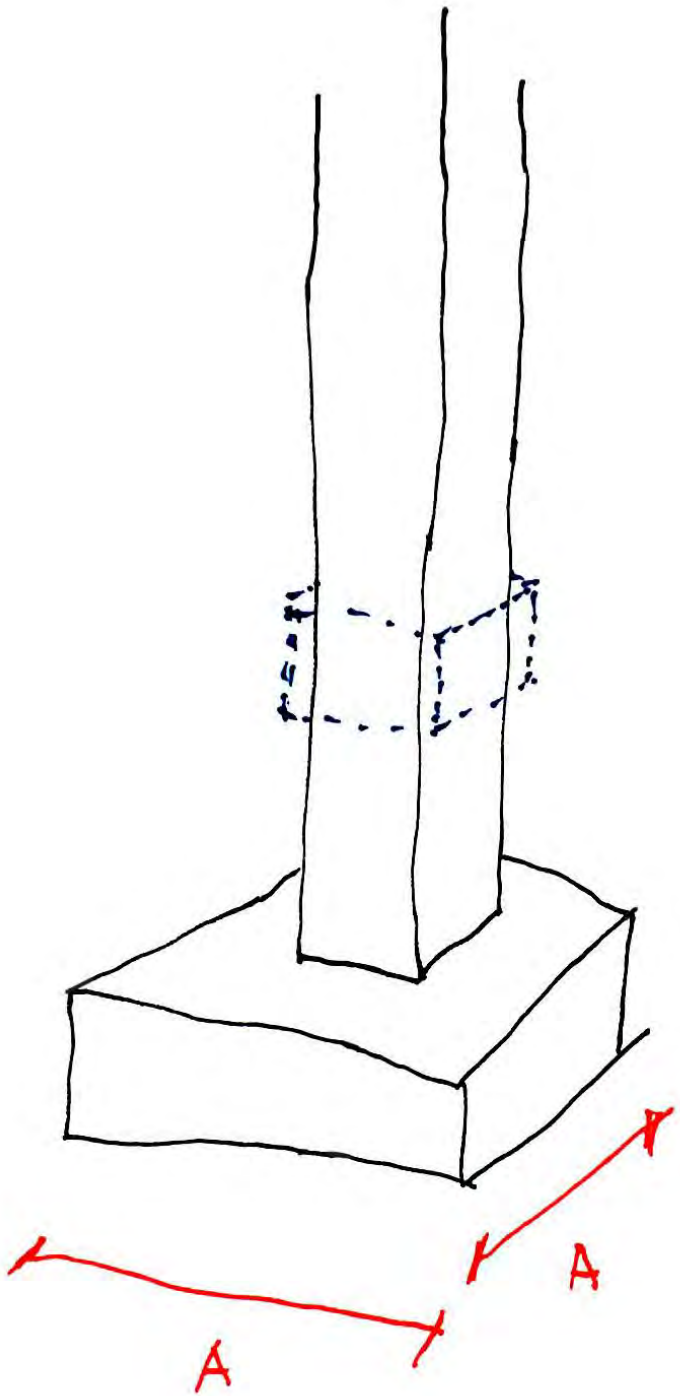


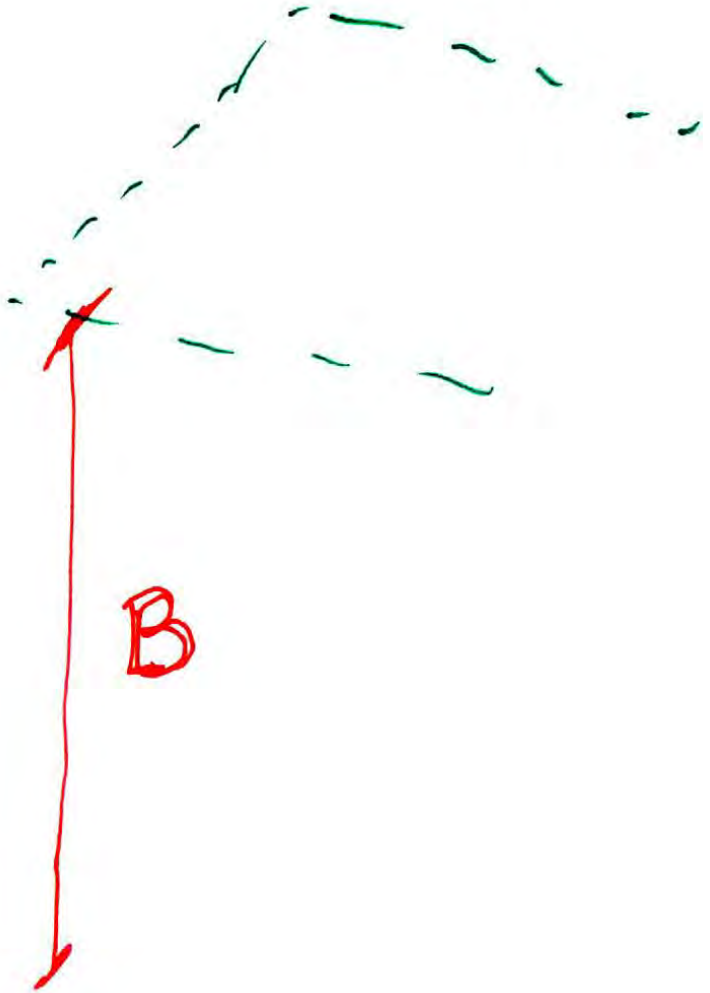
FOOTING PLAN

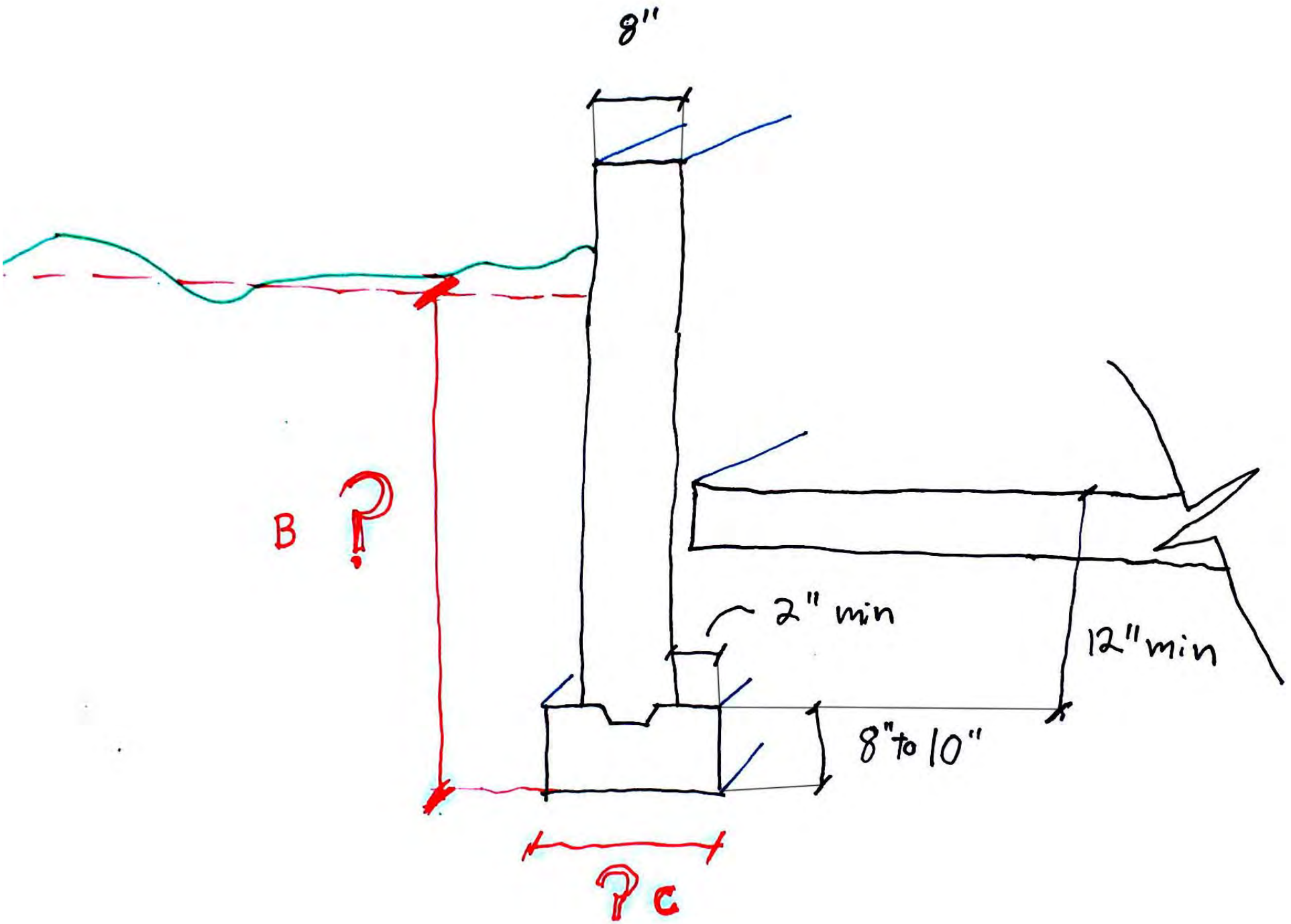


CELLAR PLAN


A
B
C
D
E
44'-11 1/32"
14'-1 17/32"
15'-4 23/32"
6'-4"
9'-0 25/32"
1
2
3
4
5
25'-5 17/32"
8'-1 1/32"
3'-1 15/16"
3'-8 7/16"
10'-8 1/8"
PIT
CLERESTORY WINDOW
LOLLIPOP COLUMN
OPENING
COLUMN FOOTING
WALL FOOTING
FOUNDATION WALL
0
4'
8'


A
A


B


8"
B
?
2" min
12" min
8" to 10"
?
C

Foundation design

A foundation design strategy:
Utilize both your borings report and your allowable weights chart

- Design your project cellar to have perimeter foundation wall and at least one column with column footing. (Use an Excel chart)
- Calculate what surface area you need to support your structure in square feet for each bearing material.
- Use the surface area calculations to determine the size of your column footing and wall footing

Note, this is a simplified design using typical conditions and values. A complete foundation design would need to include at least lateral forces, Hydro static pressure, and earth retaining forces on the foundation wall.

TABLE R403.1(1) MINIMUM WIDTH AND THICKNESS FOR CONCRETE FOOTINGS FOR LIGHT-FRAME CONSTRUCTION (inches)

SNOW LOAD OR ROOF LIVE LOAD	STORY AND TYPE OF STRUCTURE WITH LIGHT FRAME	LOAD-BEARING VALUE OF SOIL (psf)					
		1500	2000	2500	3000	3500	4000
20 psf	1 story–slab-on-grade	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	1 story–with crawl space	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	1 story–plus basement	18 × 6	14 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	2 story–slab-on-grade	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	2 story–with crawl space	16 × 6	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	2 story–plus basement	22 × 6	16 × 6	13 × 6	12 × 6	12 × 6	12 × 6
	3 story–slab-on-grade	14 × 6	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	3 story–with crawl space	19 × 6	14 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	3 story–plus basement	25 × 8	19 × 6	15 × 6	13 × 6	12 × 6	12 × 6
30 psf	1 story–slab-on-grade	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	1 story–with crawl space	13 × 6	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	1 story–plus basement	19 × 6	14 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	2 story–slab-on-grade	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	2 story–with crawl space	17 × 6	13 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	2 story–plus basement	23 × 6	17 × 6	14 × 6	12 × 6	12 × 6	12 × 6
	3 story–slab-on-grade	15 × 6	12 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	3 story–with crawl space	20 × 6	15 × 6	12 × 6	12 × 6	12 × 6	12 × 6
	3 story–plus basement	26 × 8	20 × 6	16 × 6	13 × 6	12 × 6	12 × 6

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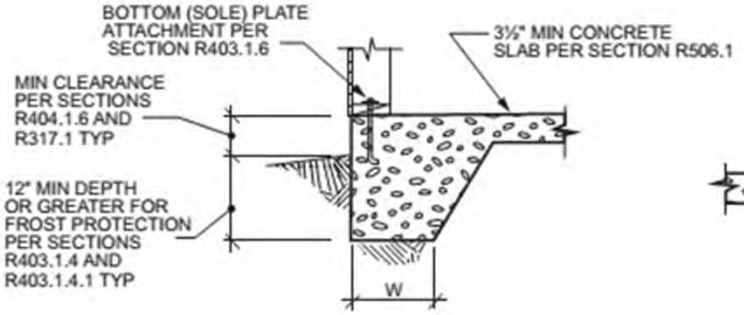
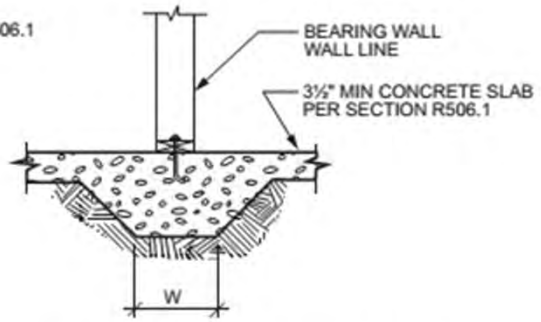
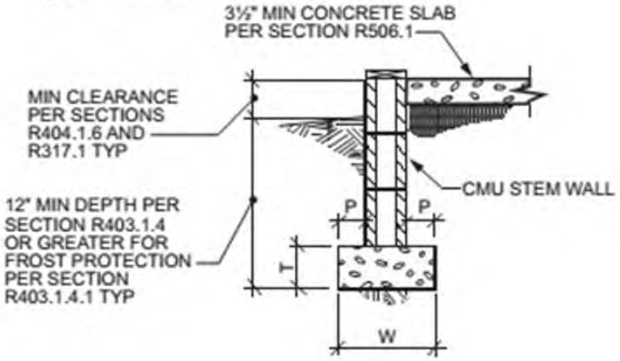


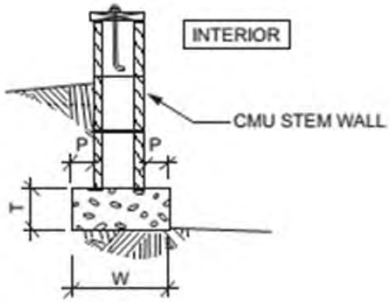
1 MONOLITHIC SLAB-ON-GROUND WITH TURNED-DOWN FOOTING
SCALE: NOT TO SCALE



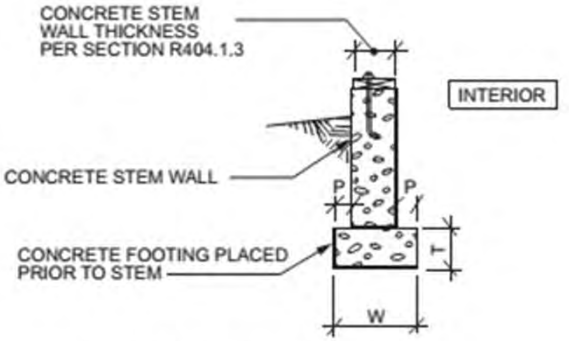
2 THICKENED SLAB-ON-GROUND FOOTING AT BEARING WALLS OR BRACED WALL LINES
SCALE: NOT TO SCALE



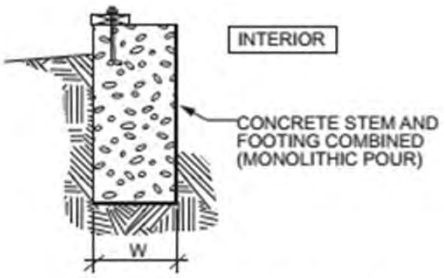
3 SLAB-ON-GROUND WITH MASONRY STEM WALL AND SPREAD FOOTING
SCALE: NOT TO SCALE



4 BASEMENT OR CRAWL SPACE WITH MASONRY WALL AND SPREAD FOOTING
SCALE: NOT TO SCALE



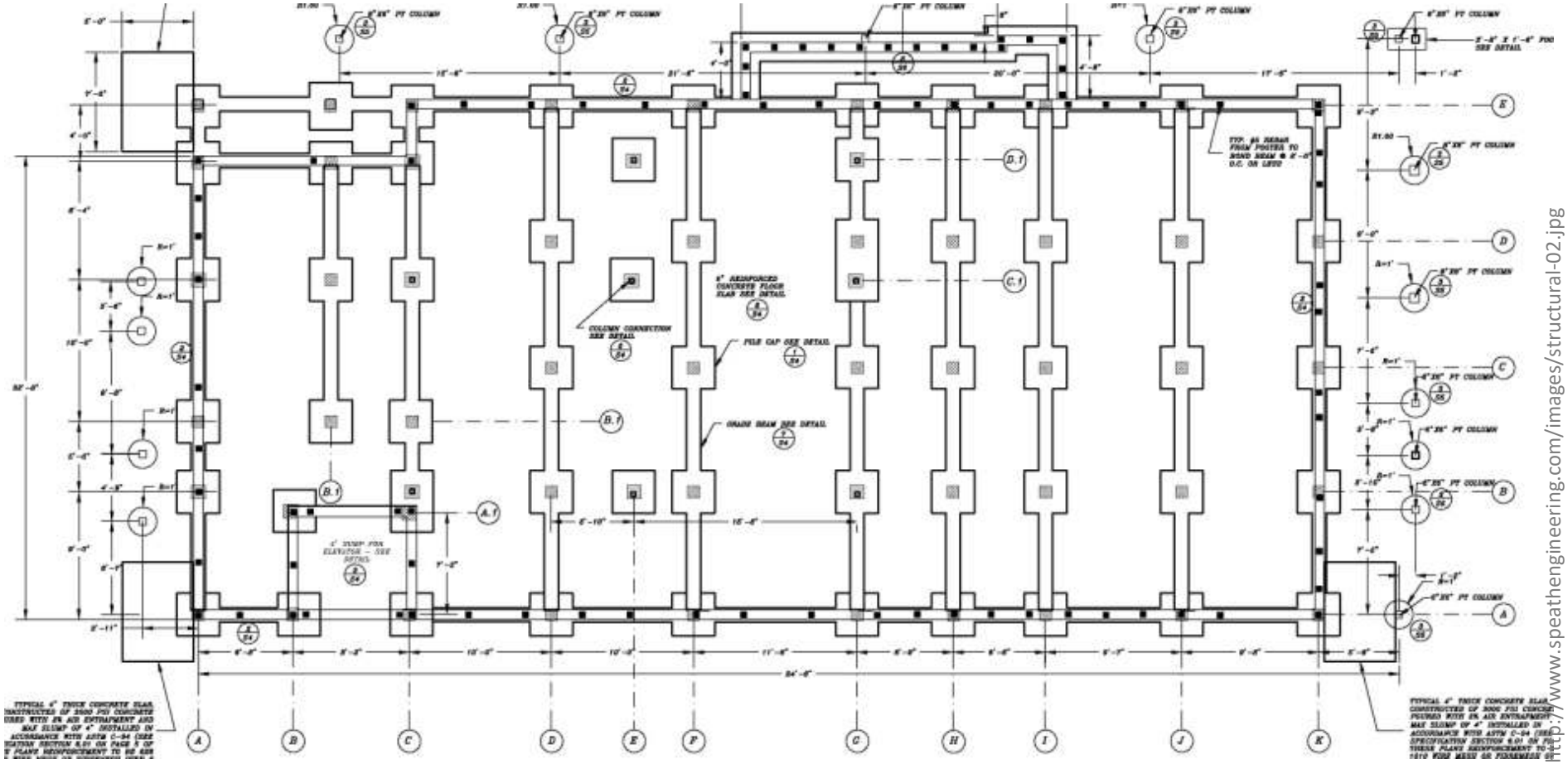
5 BASEMENT OR CRAWL SPACE WITH CONCRETE WALL AND SPREAD FOOTING
SCALE: NOT TO SCALE



6 BASEMENT OR CRAWL SPACE WITH FOUNDATION WALL BEARING DIRECTLY ON SOIL
SCALE: NOT TO SCALE

Assignment **B02 all plans**

Based on the drawings and pictures of your case study create the following drawings:



http://www.speathengineering.com/images/structural-02.jpg

TABLE R404.1.2(1) MINIMUM HORIZONTAL REINFORCEMENT FOR CONCRETE BASEMENT WALLS

MAXIMUM UNSUPPORTED HEIGHT OF BASEMENT WALL (feet)	LOCATION OF HORIZONTAL REINFORCEMENT
≤ 8	One No. 4 bar within 12 inches of the top of the wall story and one No. 4 bar near mid-height of the wall story.
> 8	One No. 4 bar within 12 inches of the top of the wall story and one No. 4 bar near third points in the wall story.

HEIGHT OF BASEMENT WALL > 8

https://cdnassets.hw.net/dims4/GG/ac2b992/2147483647/resize/876x%3E/quality/90/?url=https%3A%2F%2Fcdnassets.hw.net%2F49%2F70%2Ff6fcf9fe4830b13dd41201de7e6a%2F10-uhler-seismic.jpg

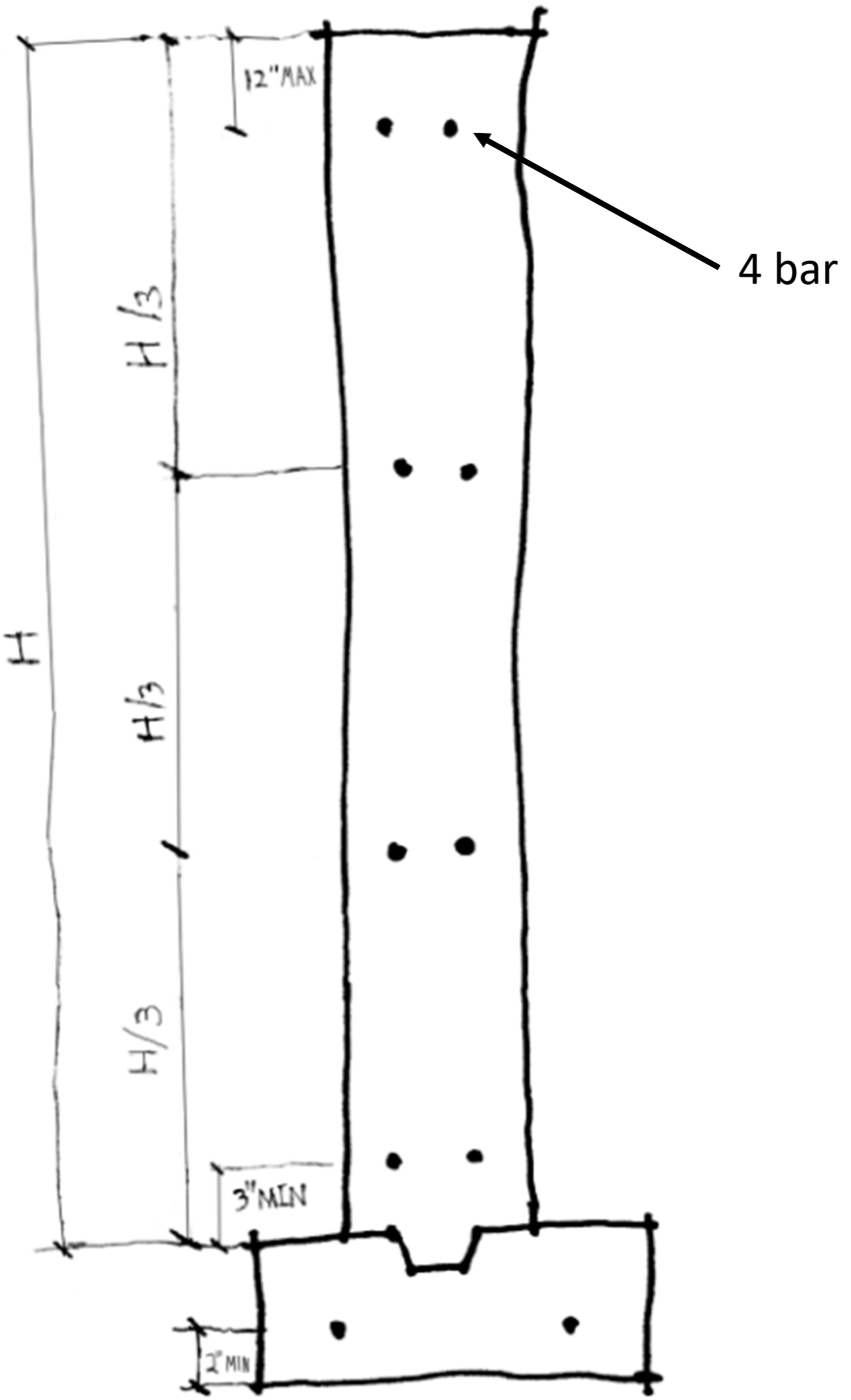
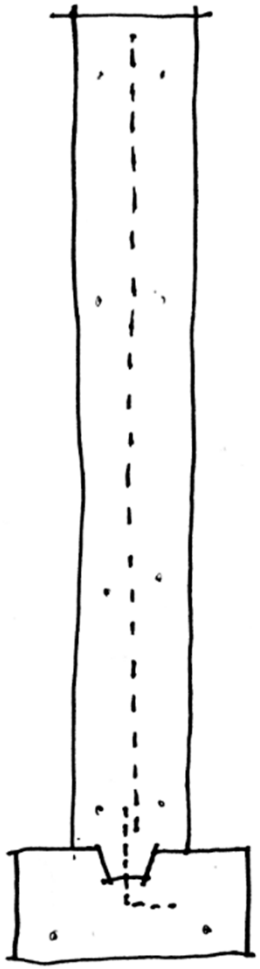


TABLE R404.1.2(3) MINIMUM VERTICAL REINFORCEMENT FOR 8-INCH (203 mm) NOMINAL FLAT CONCRETE BASEMENT WALLS



VERTICAL

MAXIMUM UNSUPPORTED WALL HEIGHT (feet)	MAXIMUM UNBALANCED BACKFILL HEIGHT[g] (feet)	MINIMUM VERTICAL REINFORCEMENT-BAR SIZE AND SPACING (inches)		
		Soil classes[a] and design lateral soil (psf per foot of depth)		
		GW, GP, SW, SP 30	GM, GC, SM, SM-SC and ML 45	SC, ML-CL and inorganic CL 60
8	4	NR	NR	NR
	5	NR	NR	NR
	6	NR	NR	6 @ 37
	7	NR	6 @ 36	6 @ 35
	8	6 @ 41	6 @ 35	6 @ 26
9	4	NR	NR	NR
	5	NR	NR	NR
	6	NR	NR	6 @ 35
	7	NR	6 @ 35	6 @ 32
	8	6 @ 36	6 @ 32	6 @ 23
	9	6 @ 35	6 @ 25	6 @ 18
10	4	NR	NR	NR
	5	NR	NR	NR
	6	NR	NR	6 @ 35
	7	NR	6 @ 35	6 @ 29
	8	6 @ 35	6 @ 29	6 @ 21
	9	6 @ 34	6 @ 22	6 @ 16
	10	6 @ 27	6 @ 17	6 @ 13

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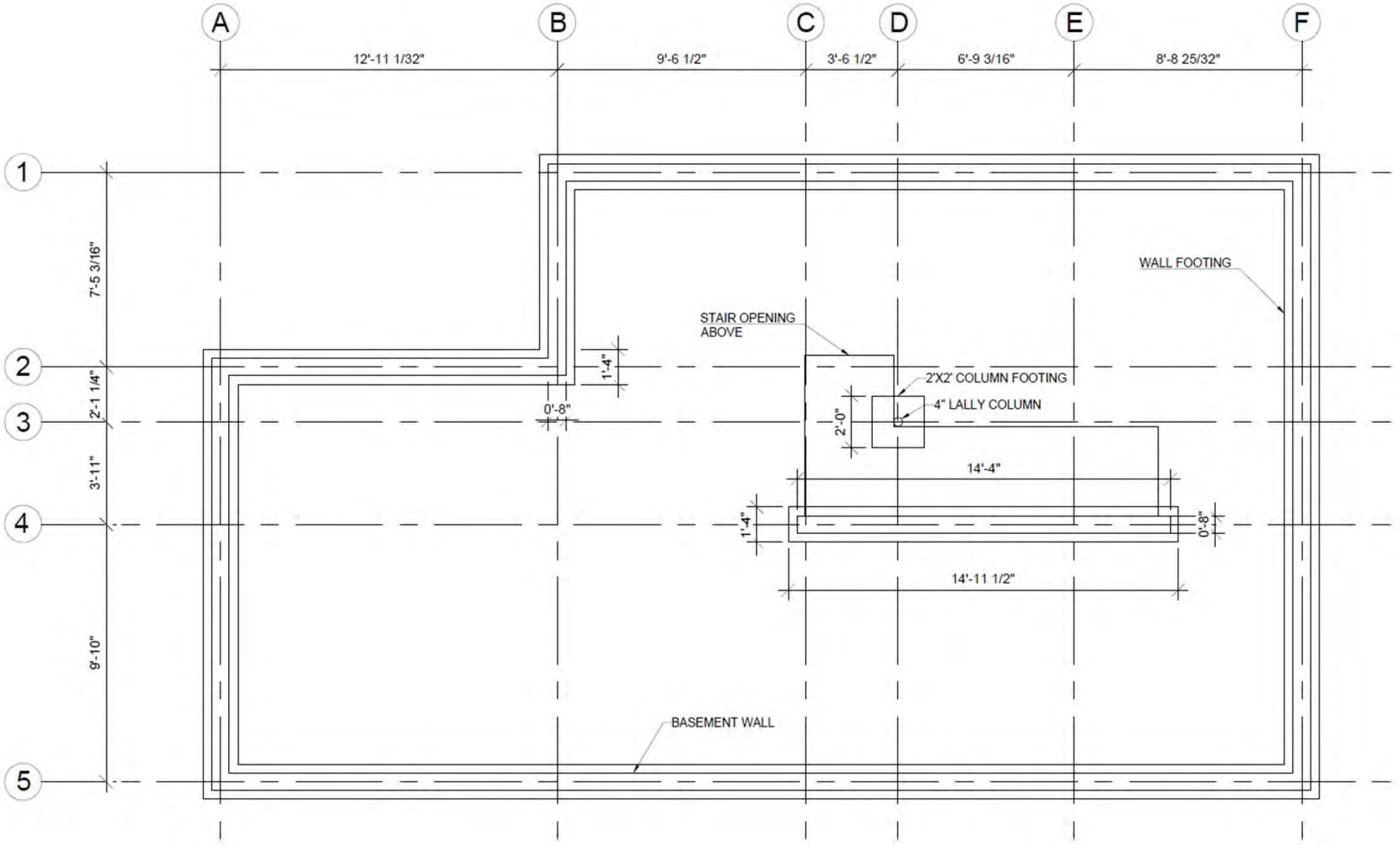
FOOTING PLAN

(example)



CELLAR PLAN
(example)