# ARCH 2231
# BUILDING TECHNOLOGY II

Aptekar Milan 2019

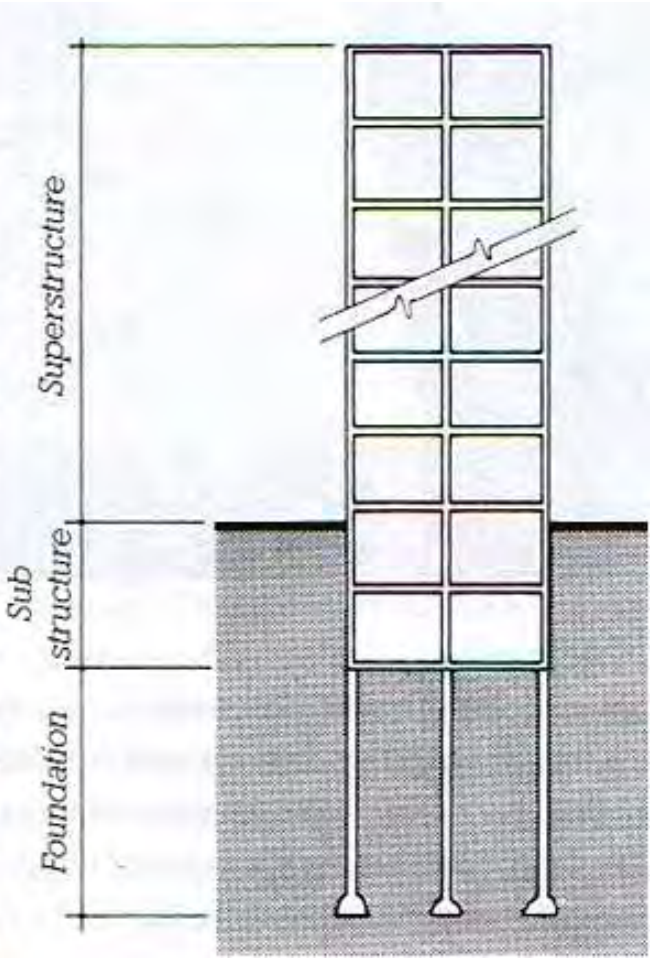
# Class Overview:

**Discussion / Lecture :**
Foundation  Calculations
Building codes and foundations
Foundation plan versus basement plan

**Lab:**
Assignment B03 Joist Plans
Foundation (footing) plan
Basement plan

**Upcoming:**
Class number 15 (Midterm) Thursday, 03, 24, 2022
B04 structural foundation footing plan
Studs layout
Wall types

# 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.*

# TYPES OF SETTLEMENT:

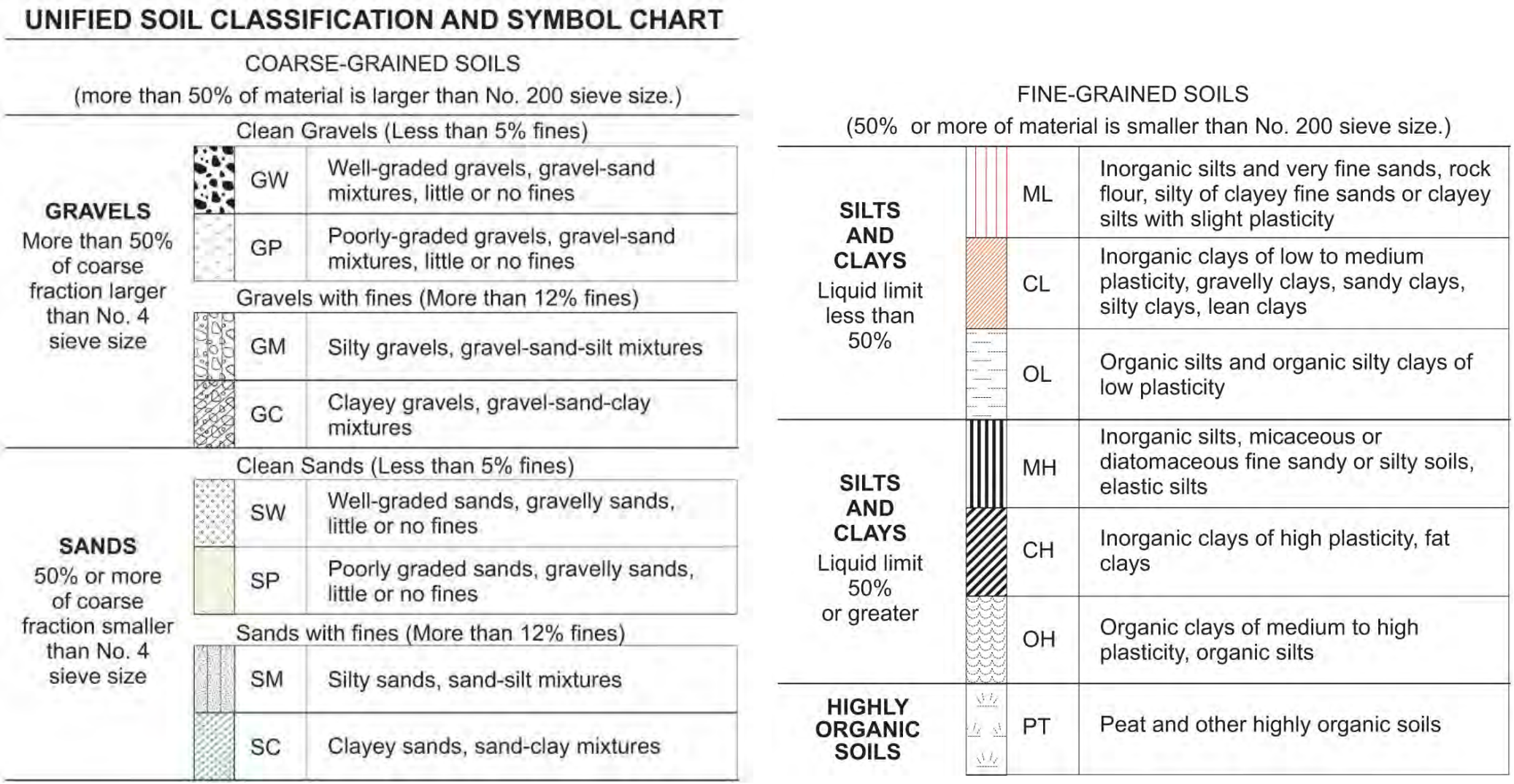
1. *Uniform: Equal across foundation = little or no damage*
2. *Differential: Columns & Bearing Walls settle different amounts = damage or failure.*


Differential settlement

The most common cause of differential settlement is multiple soil types under building.

https://www.dailymail.co.uk/news/article-2997163/Couple-s-dream-home-collapsed-rubble-botched-basement-dig-sending-eight-months-pregnant-fiancee-early-labour.html

# 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 |

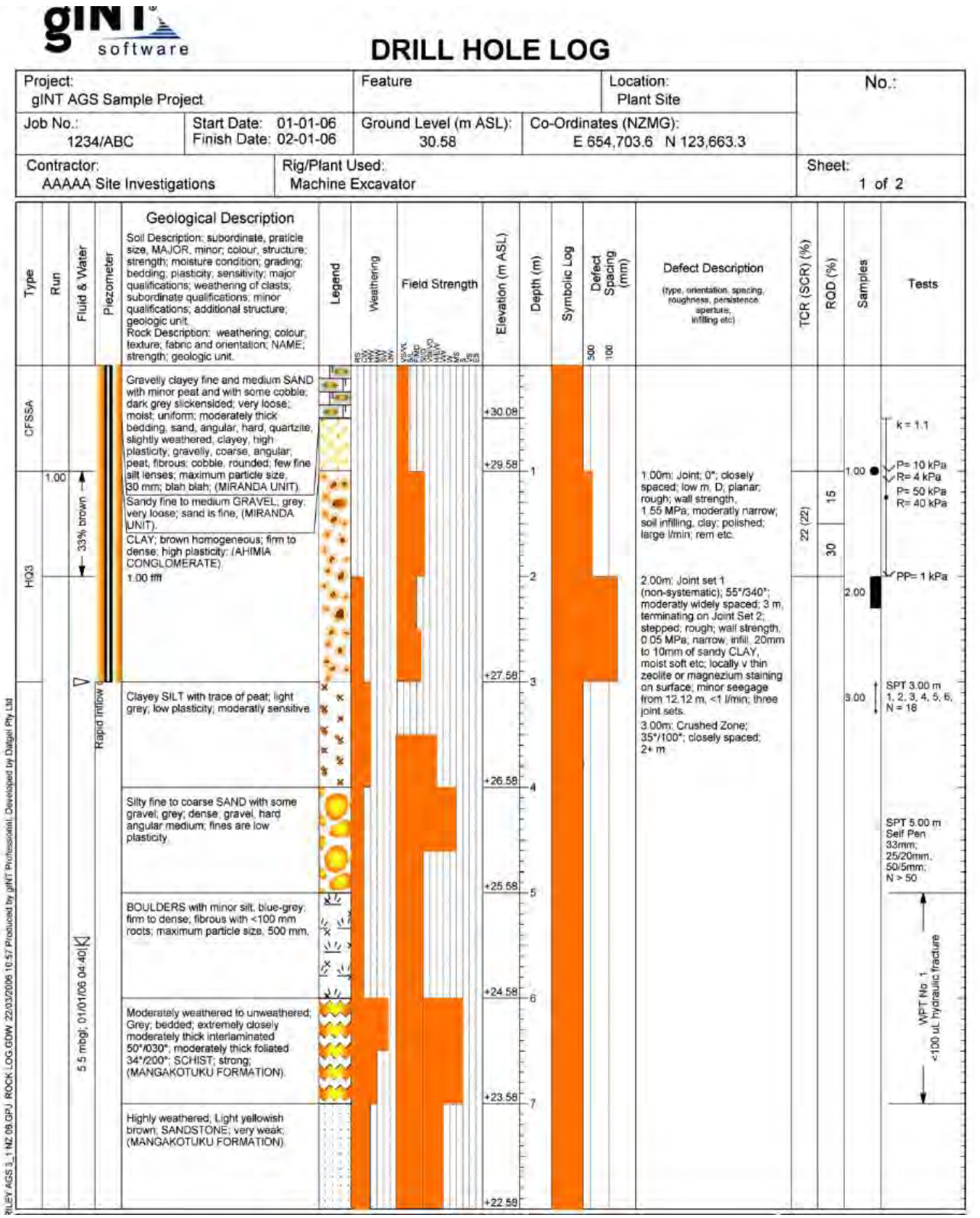
FINE-GRAINED SOILS

(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 |

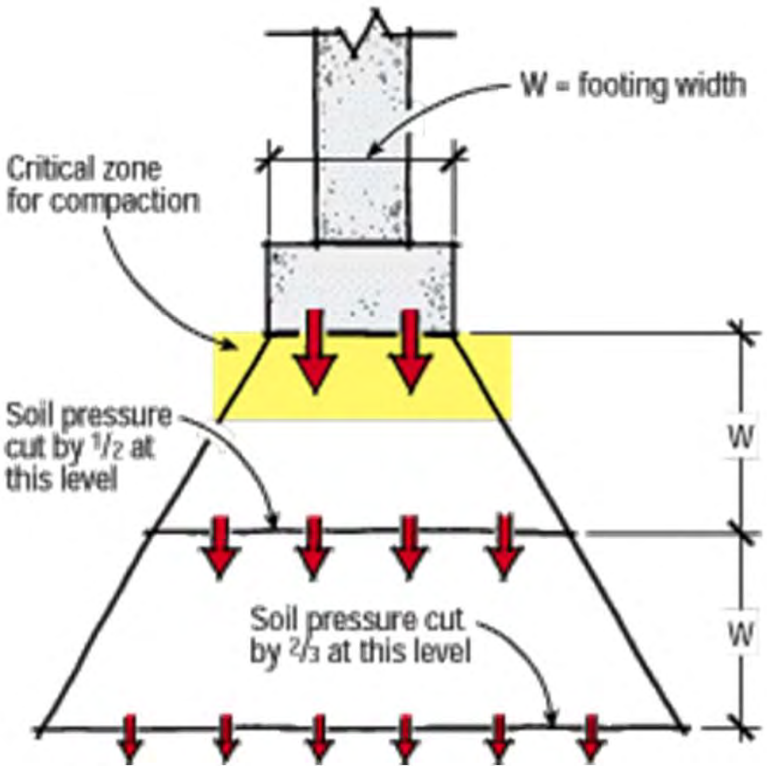
http://matrix.vtrc.virginia.edu/DATA/GINT/vdotusc.PDF

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



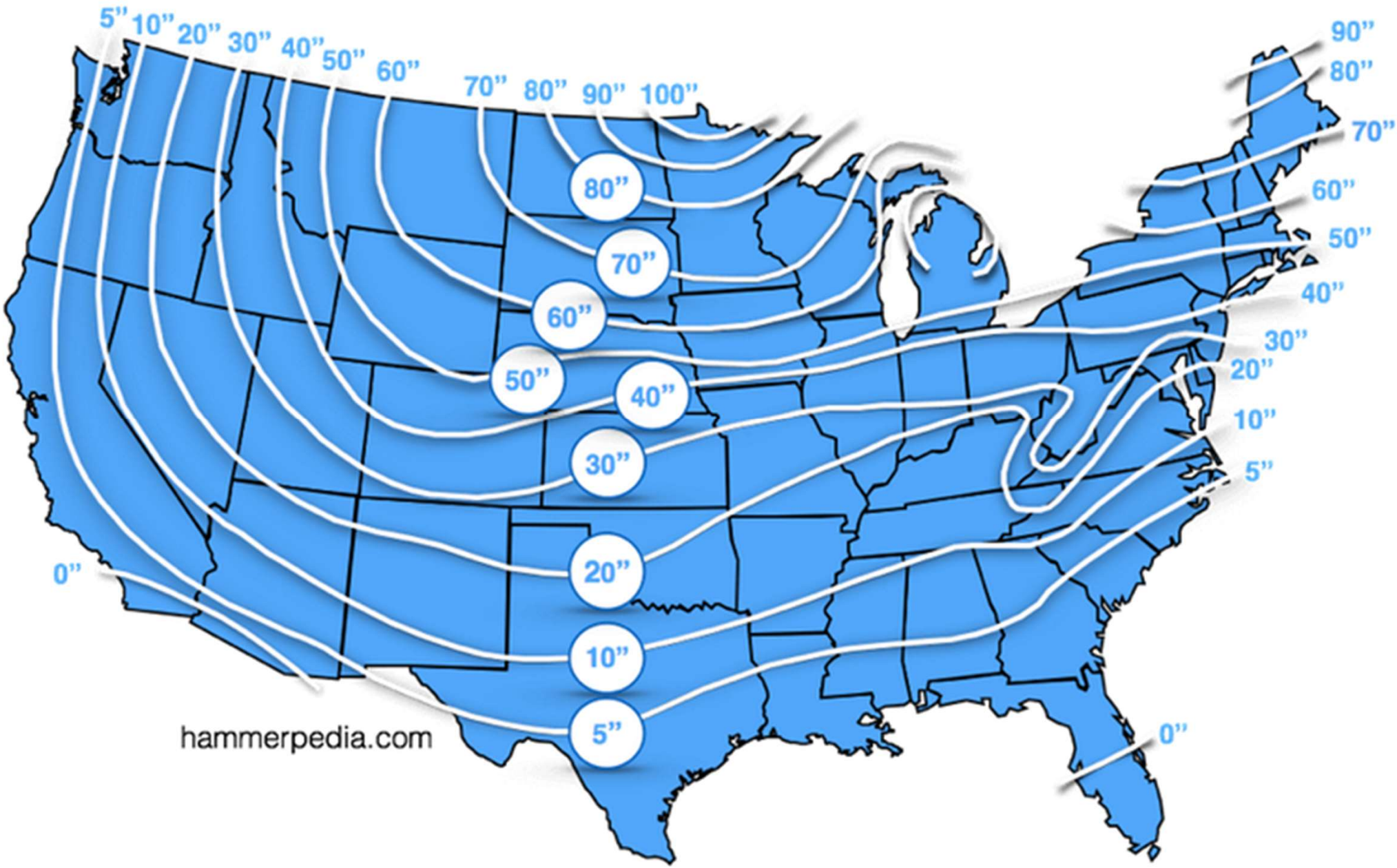

http://www.gintsoftware.com/reports_boringlogs.html

## Diminishing Soil Pressure



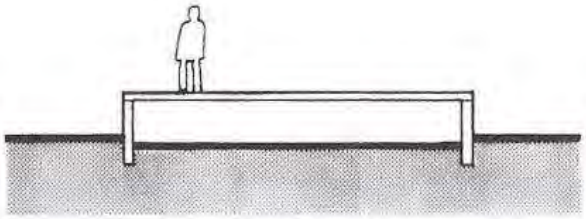

| Soil Bearing Capacities | |
|---|---|
| **Class of Materials** | **Load-Bearing Pressure (pounds per square foot)** |
| Crystalline bedrock | 12,000 |
| Sedimentary and foliated rock | 4,000 |
| Sandy gravel and/or gravel (GW and GP) | 3,000 |
| Sand, silty sand, clayey sand, silty gravel and clayey 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 |
| Residential Code 2020 of New York State | |

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

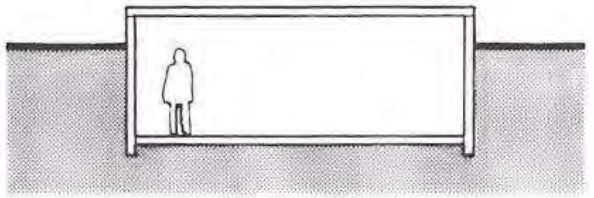


# Shallow Foundations

SLAB ON GRADE



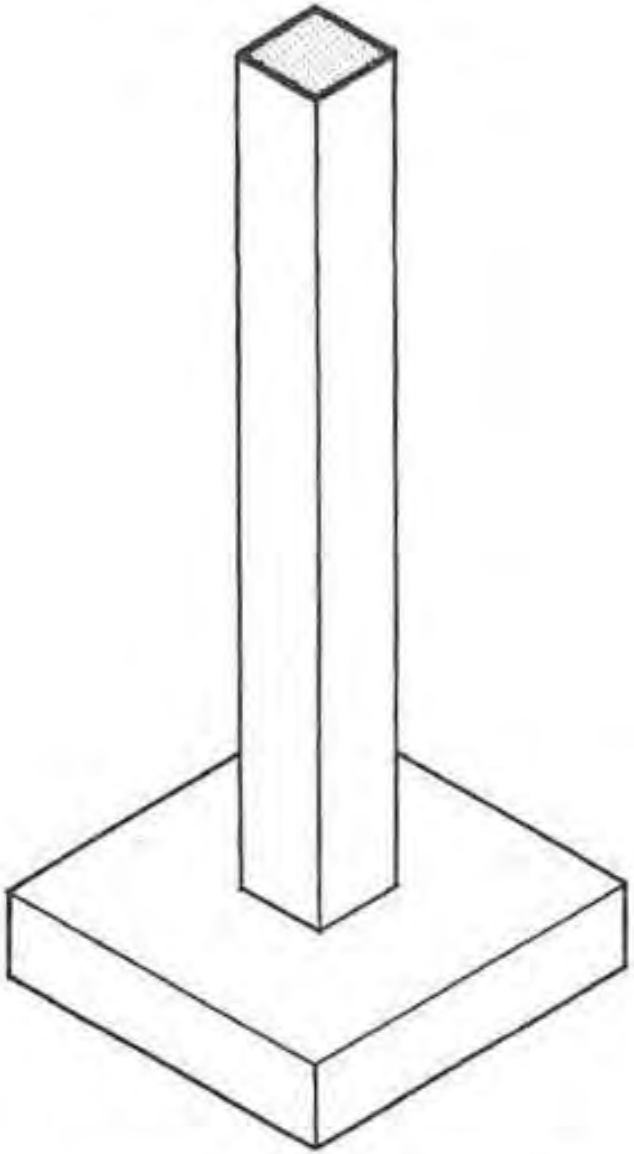
CRAWLSPACE



BASEMENT

Allen, Edward, and Joseph Iano. Fundamentals of Building Construction: Materials and Methods. 7th ed., Wiley, 2019. [PowerPoint document]

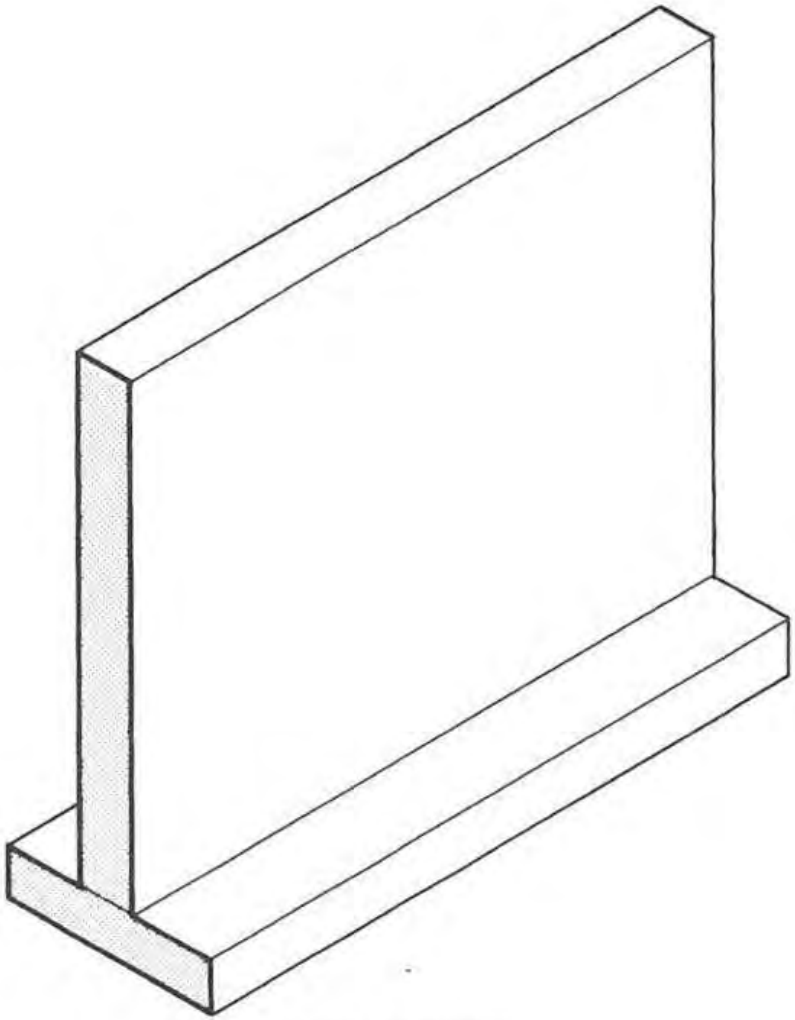
# COLUMN FOOTING



COLUMN FOOTING

Allen, Edward, and Joseph Iano. Fundamentals of Building Construction: Materials and Methods. 7th ed., Wiley, 2019. [PowerPoint document]

# WALL FOOTING
# (STRIP FOOTING)



*WALL FOOTING*


Allen, Edward, and Joseph Iano. Fundamentals of Building Construction: Materials and Methods. 7th ed., Wiley, 2019. [PowerPoint document]

# Deep Foundations

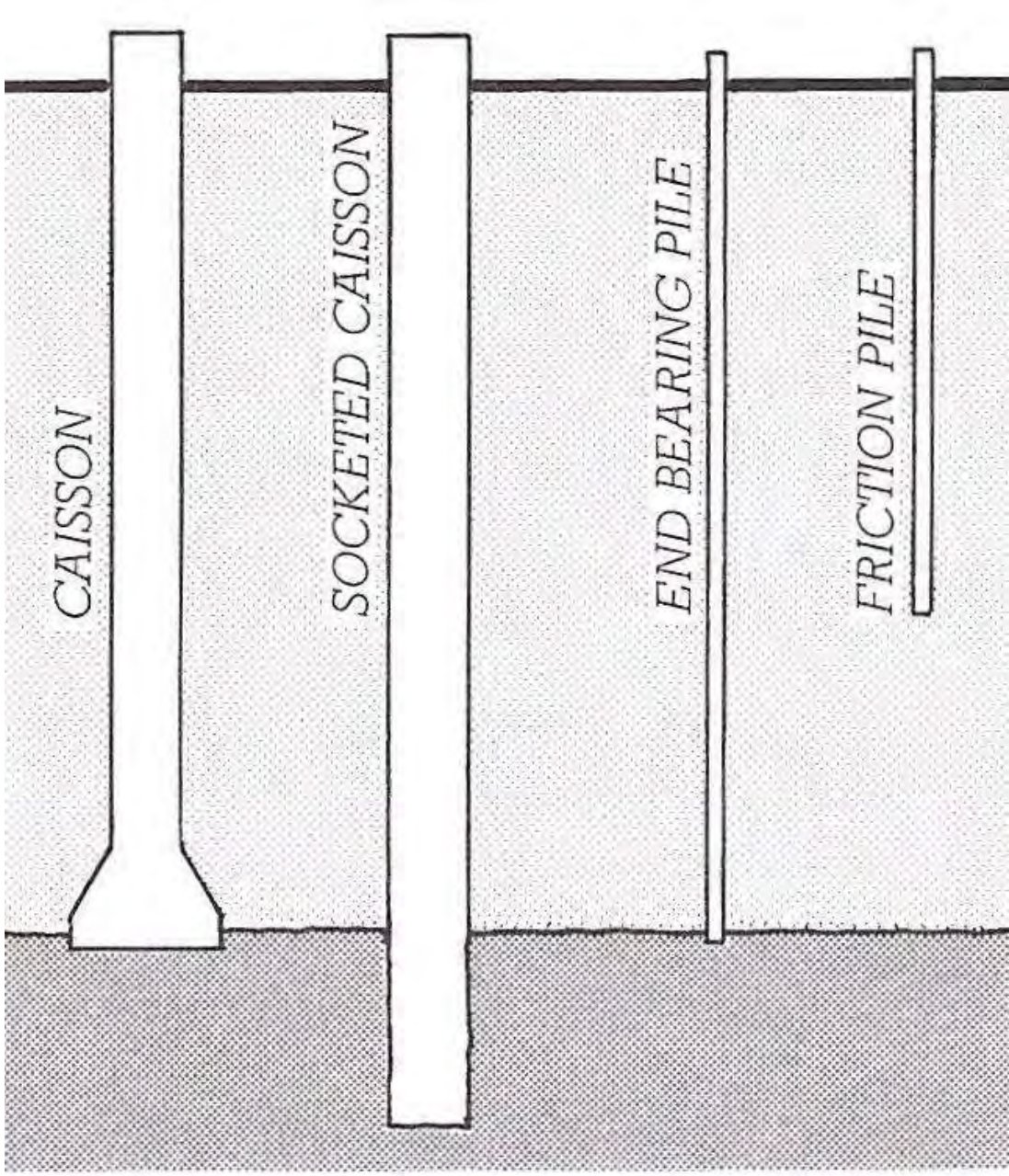
DEEP FOUNDATIONS:

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.

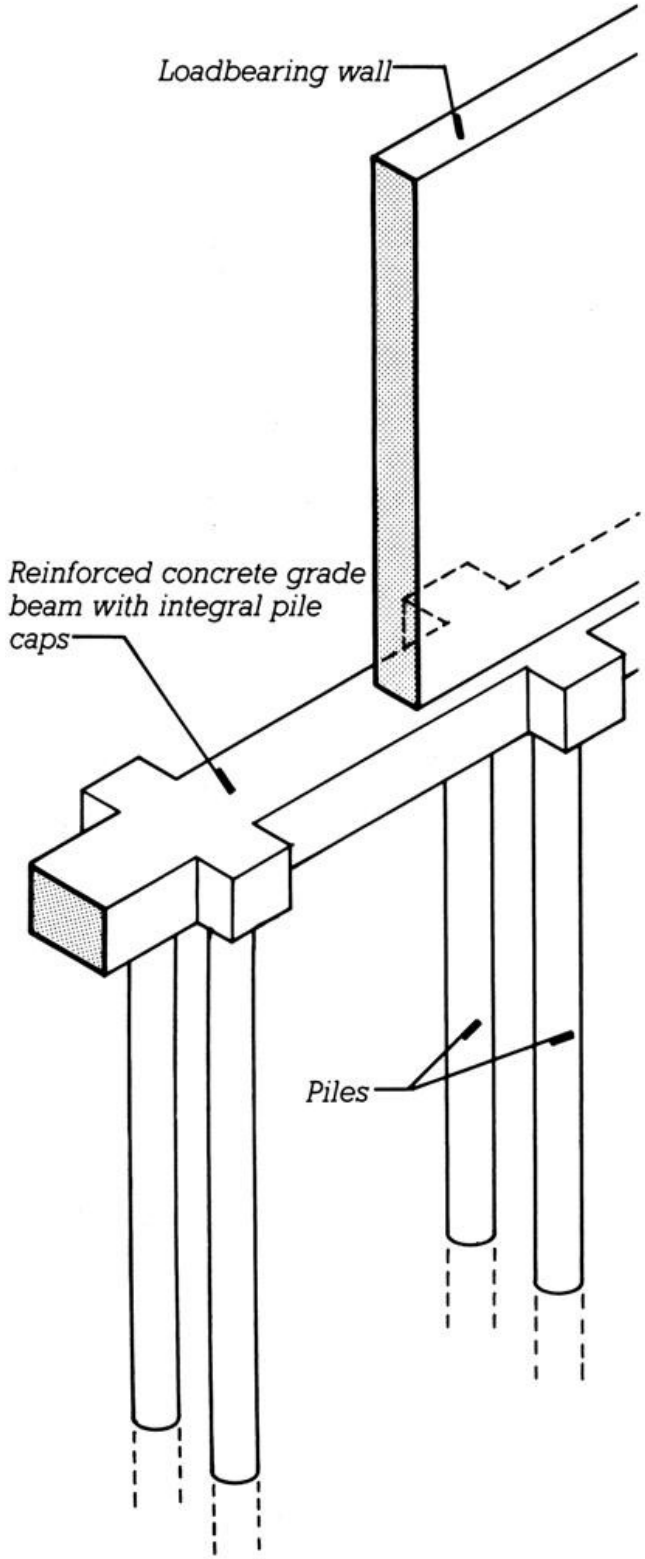



"Fundamentals of Building Construction / Materials and Methods" Allen & Wiley

# Piles and Grade Beams

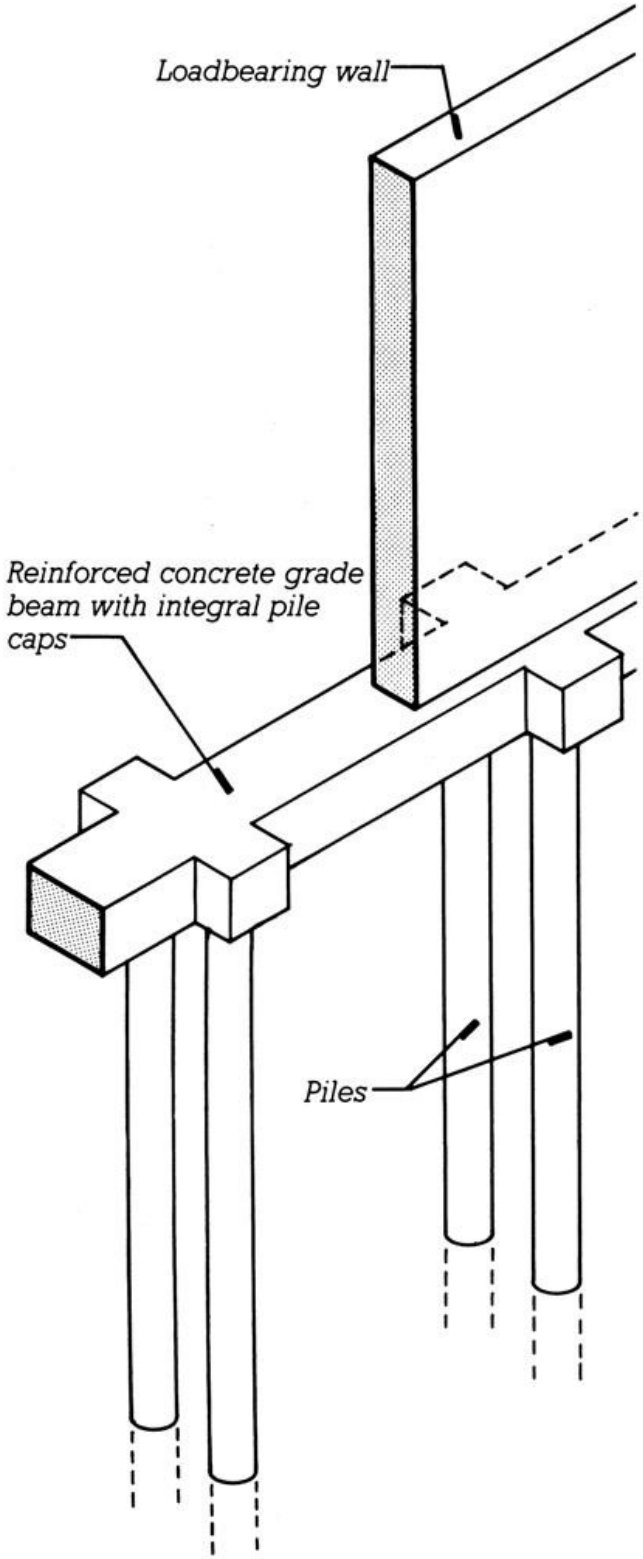
*Pile caps* share loads among clustered piles.

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




Allen, Edward, and Joseph Iano. Fundamentals of Building Construction: Materials and Methods. 7th ed., Wiley, 2019. [PowerPoint document]

# GRADE BEANS:




Allen, Edward, and Joseph Iano. Fundamentals of Building Construction: Materials and Methods. 7th ed., Wiley, 2019. [PowerPoint document]

https://www.oysterworks.net/helical-pile-and-grade-beam-foundation/

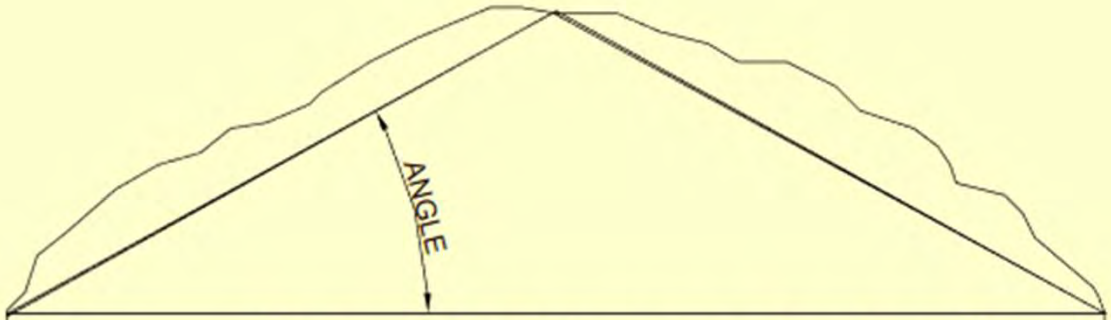
# Foundation design

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

# Snow Loads

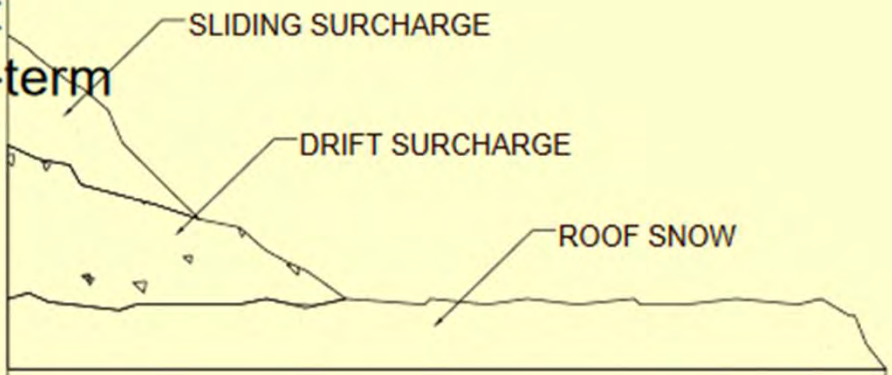
https://www.edtengineers.com/sites/default/files/2019-02/GettyImages-182865717.jpg

# Snow Loads



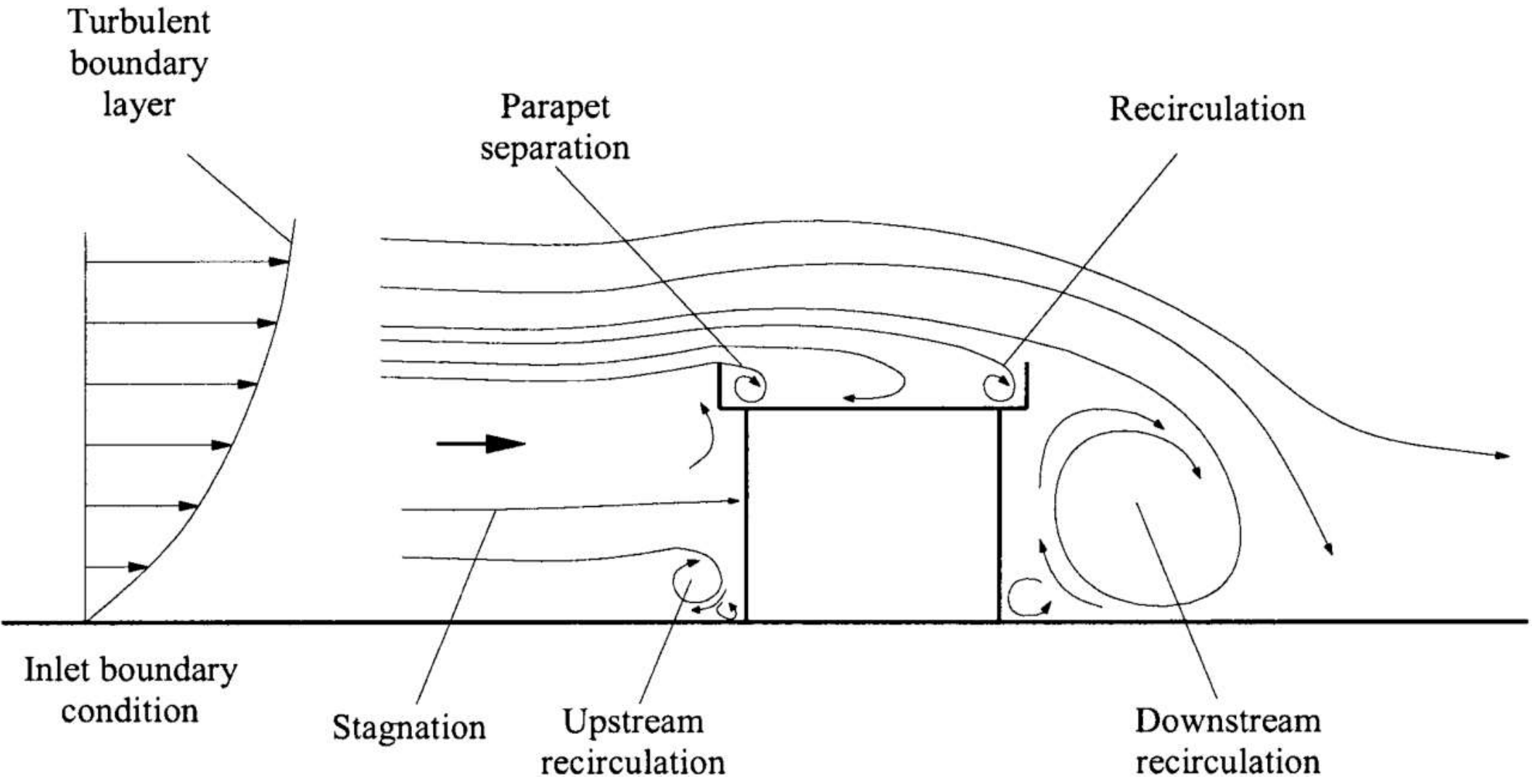

Note a 15% increase in the allowable capacity of wood for loads that include snow, which is a short-term load

| 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

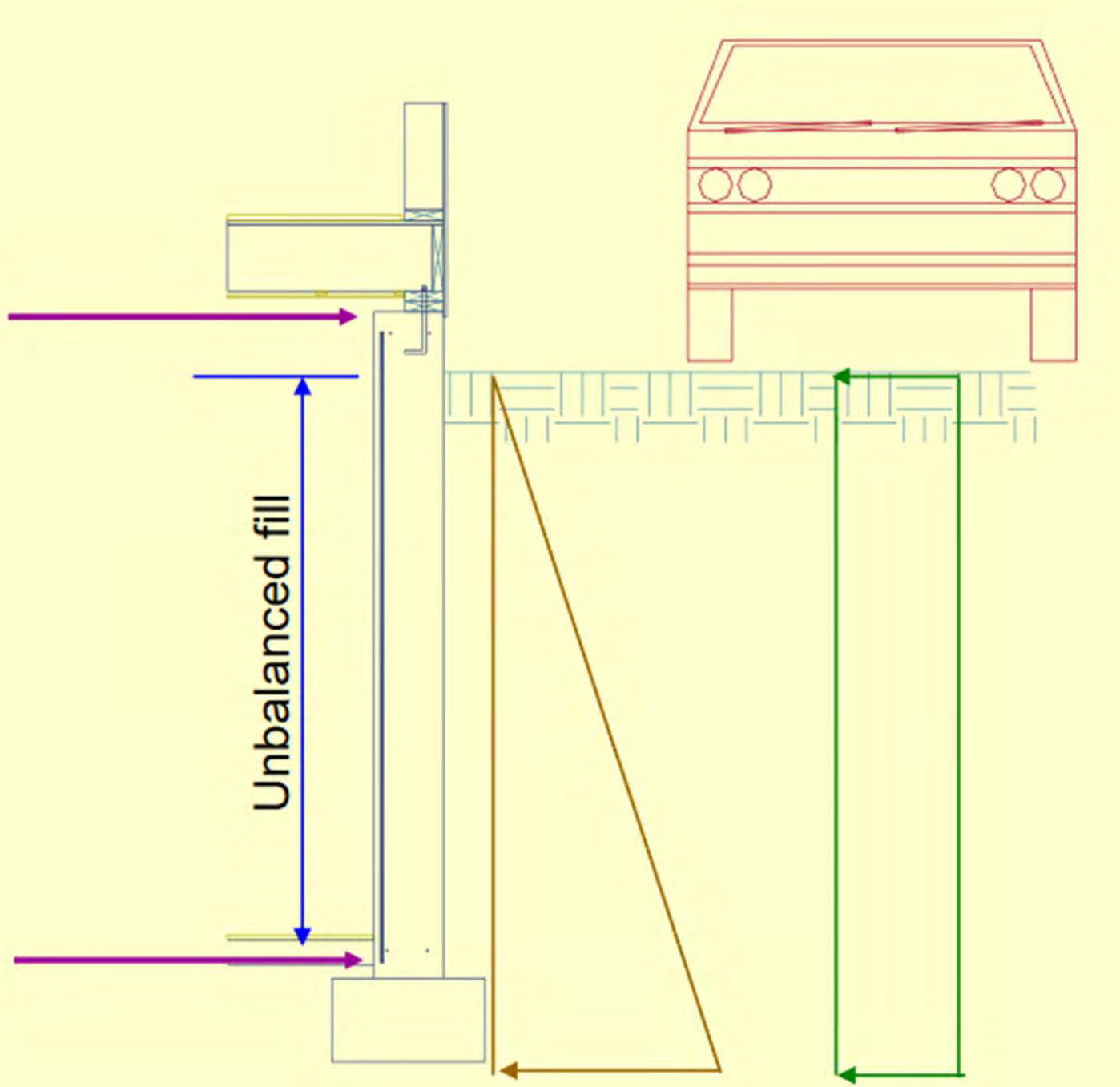


TABLE 3.0a
TYPICAL DEAD LOADS FOR COMMON
RESIDENTIAL CONSTRUCTIONS

| | | | |
|---|---|---|---|
| **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) | CONCENTRATED (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

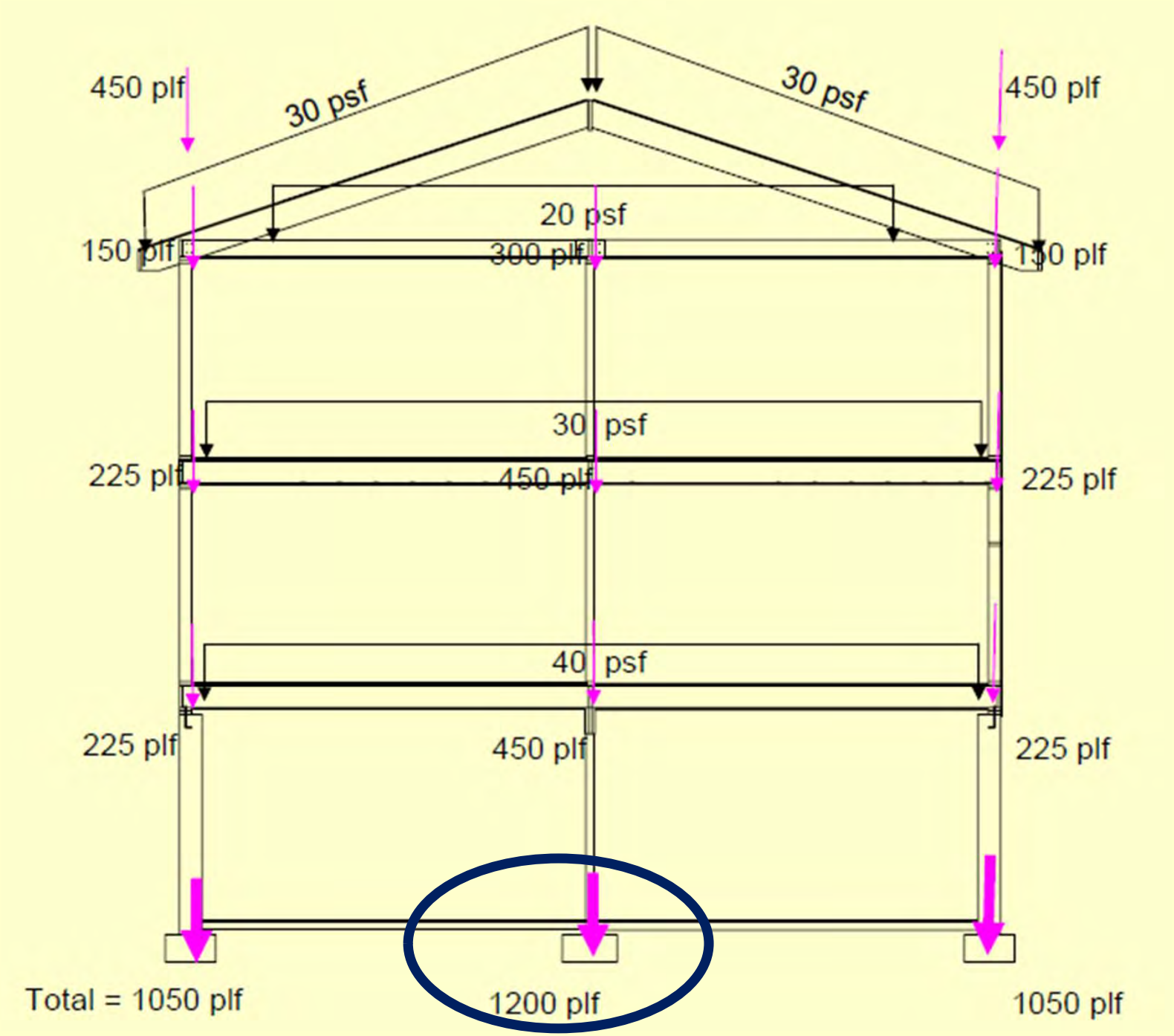
# LIVE LOADS

## [THE MASSACHUSETTS STATE BUILDING CODE]

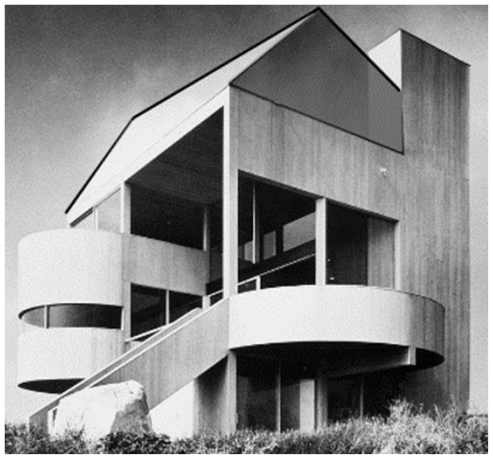
| OCCUPANCY OR USE | UNIFORM (psf) | CONCEN-TRATED (lbs.) |
|---|---|---|
| 28. Residential | | |
| Group R-3 | | |
| Uninhabitable attics without storage | 10 | |
| Uninhabitable attics with storage | 20 | |
| Habitable attics and sleeping areas | 30 | |
| All other areas except balconies and decks | 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



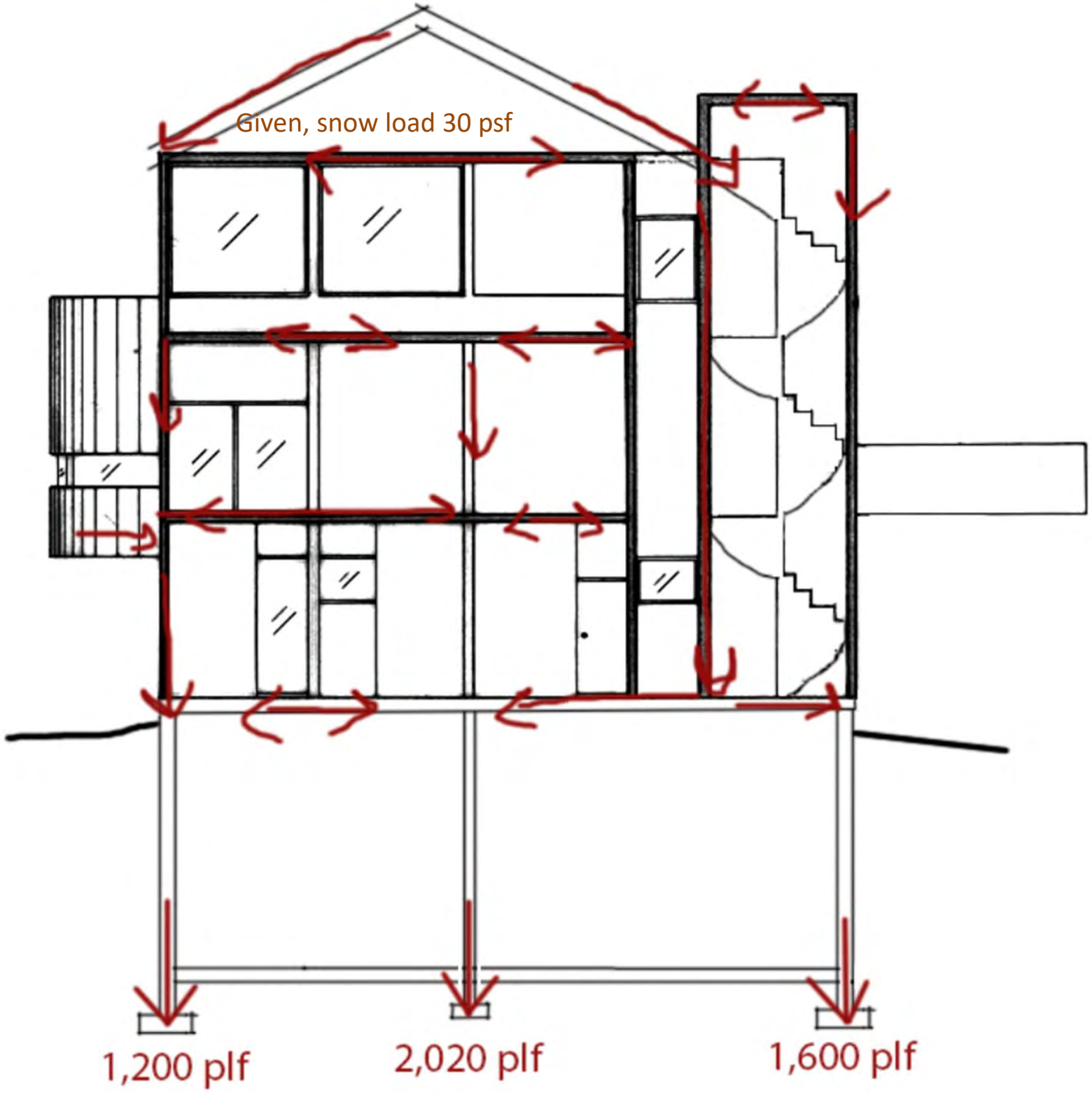


TABLE R401.4.1 PRESUMPTIVE LOAD-BEARING VALUES OF FOUNDATION MATERIALS[a]

| 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.

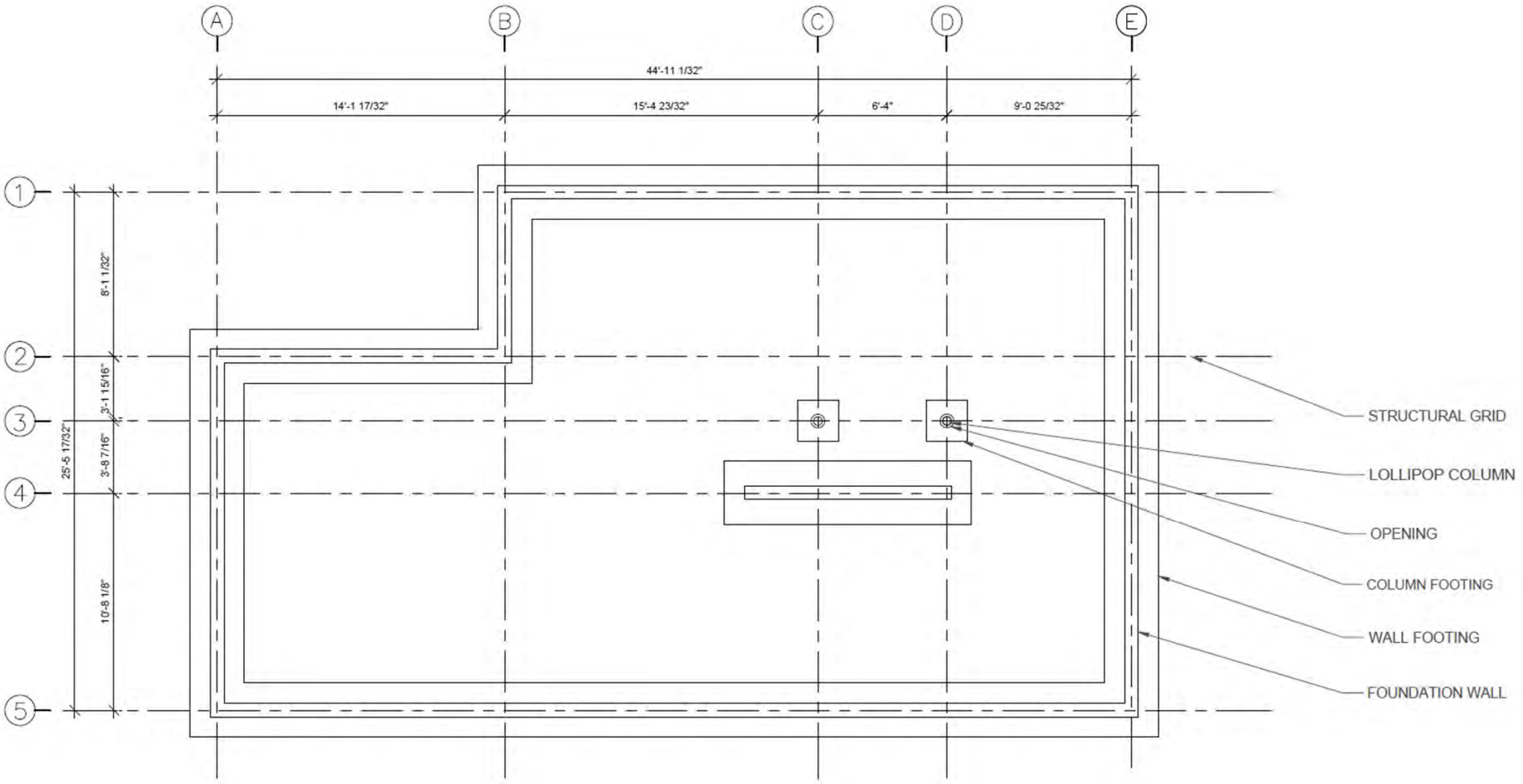
b. Where the building official determines that in-place soils with an allowable bearing capacity of less than 1,500 psf are likely to be present at the site, the allowable bearing capacity shall be determined by a soils investigation.

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

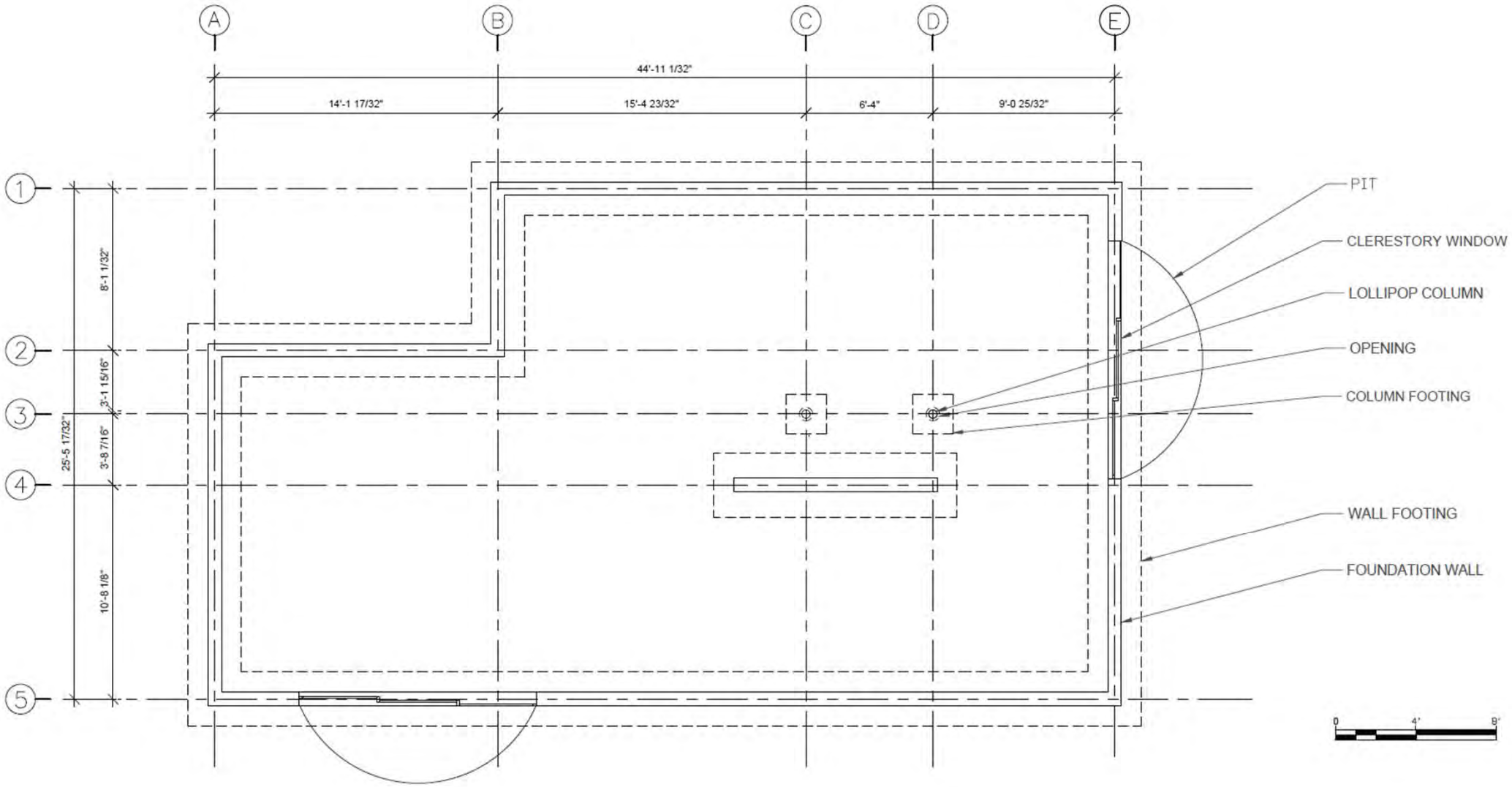
| Borings Soil Report | Depth | | |
|---|---|---|---|
| Soil type: | Meters | feet | |
| Topsoil | 1.22 | 4 | |
| Brown silty clay | 2.74 | 9 | |
| Very fine sand and gravel | 3.66 | 12 | |
| Sand and clay | 6.4 | 15 | |
| Gravel | 7.32 | 24 | |
| London clay | 88.4 | 27 | |
| Water | 35.36 | 116 | |

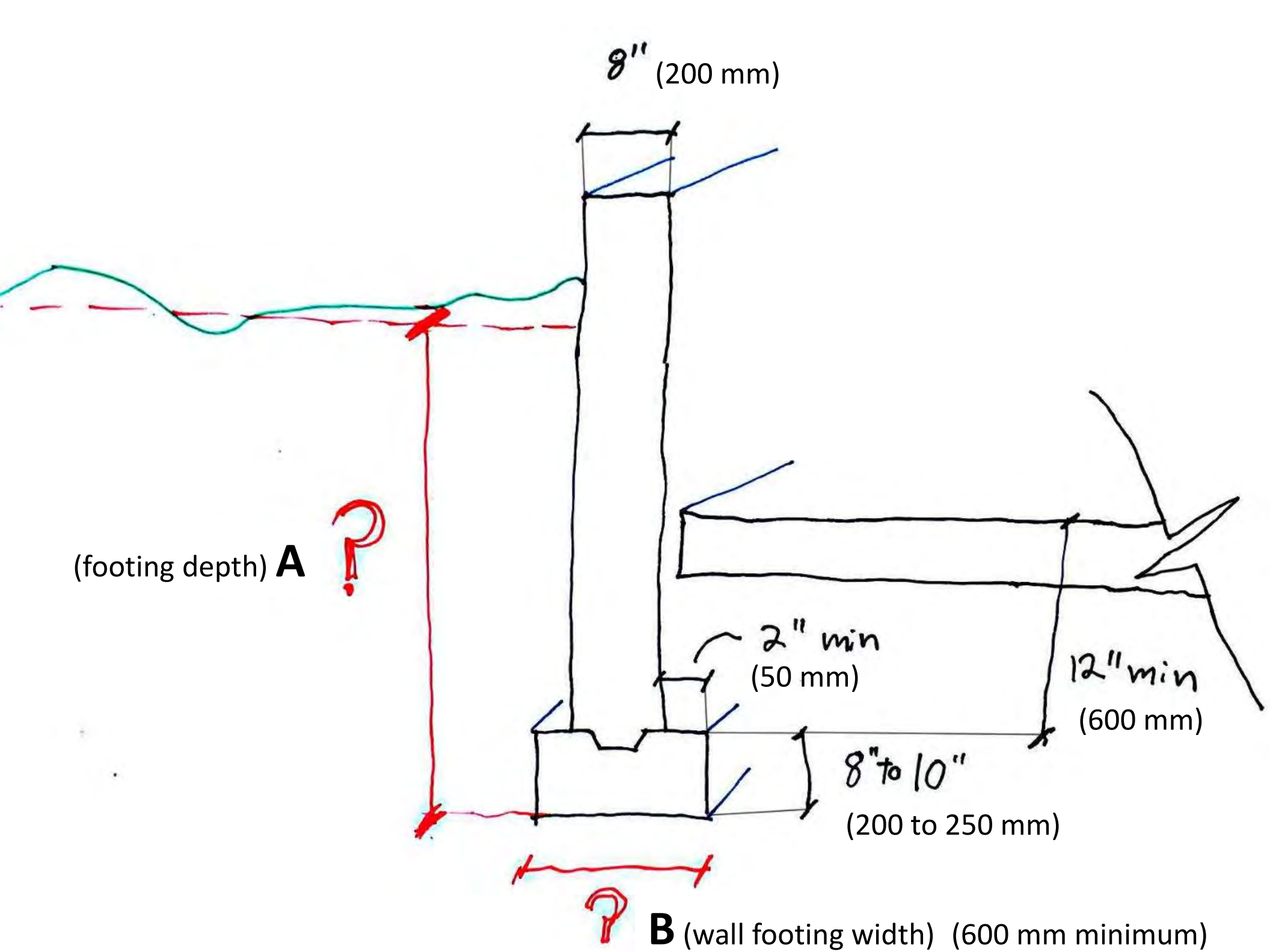
https://www.teds-fl.com/images/civil-engineering-pic6.jpg

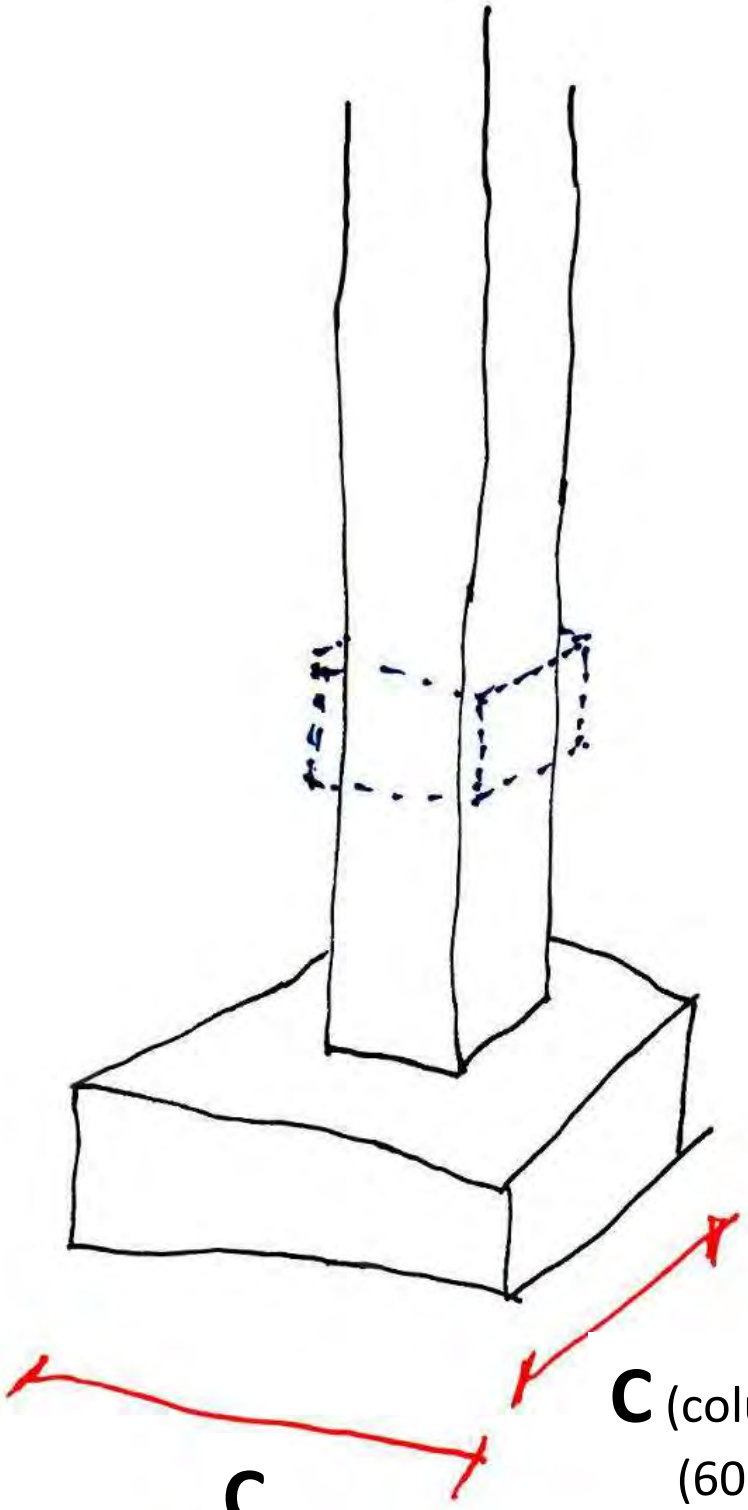
# FOOTING PLAN

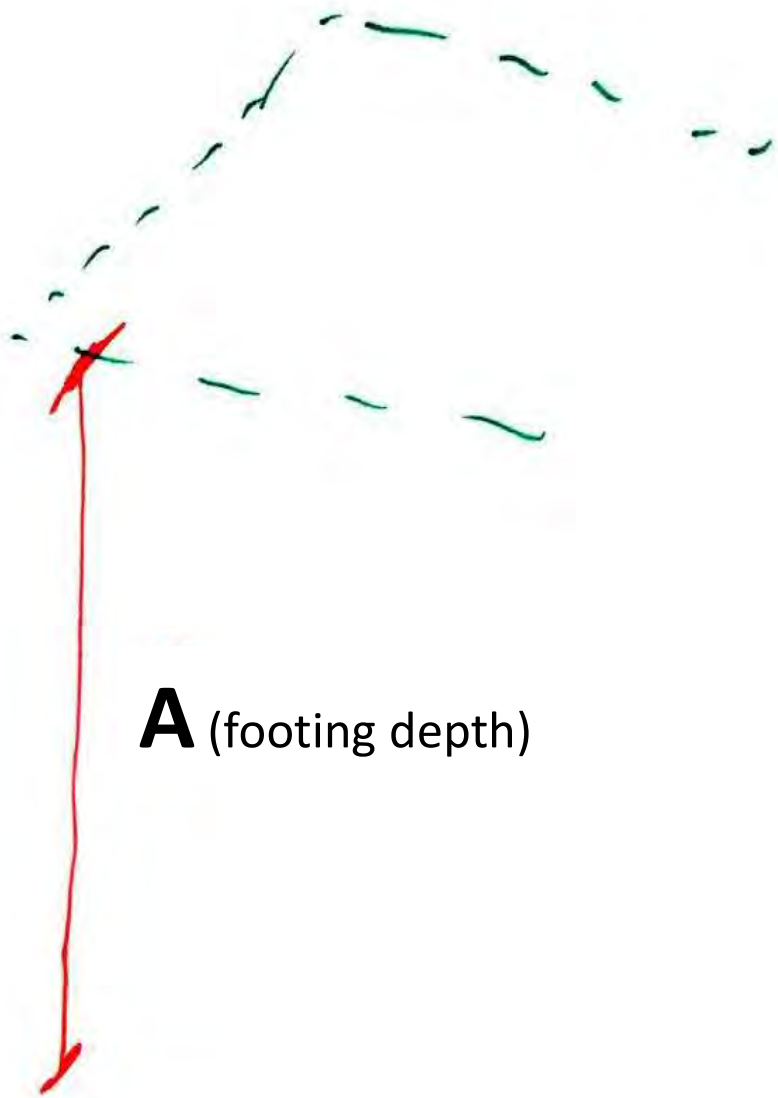


# CELLAR PLAN


A
B
C
D
E
1
2
3
4
5
44'-11 1/32"
14'-1 17/32"
15'-4 23/32"
6'-4"
9'-0 25/32"
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'


8" (200 mm)
(footing depth) A
?
2" min
(50 mm)
12" min
(600 mm)
8" to 10"
(200 to 250 mm)
?
B (wall footing width) (600 mm minimum)




**A** (footing depth)

**C** (column footing width)
(600 mm minimum)

# 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
- Compare to local code

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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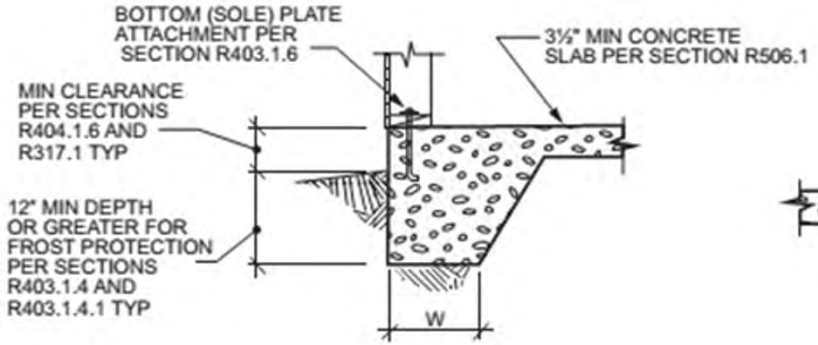
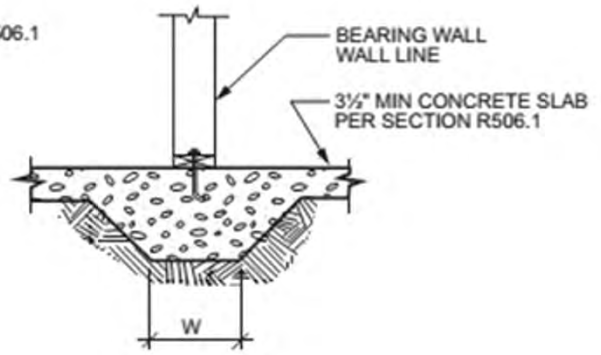
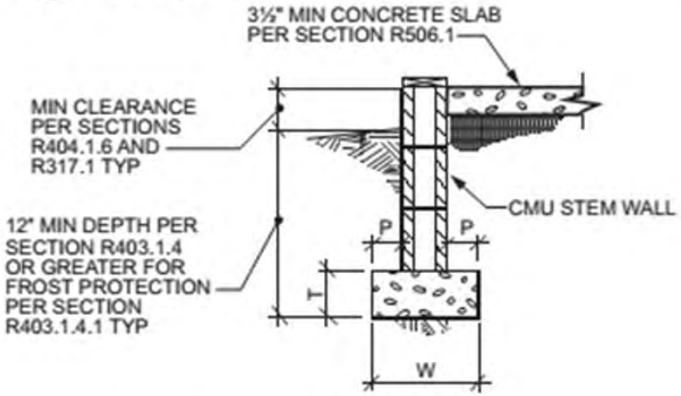


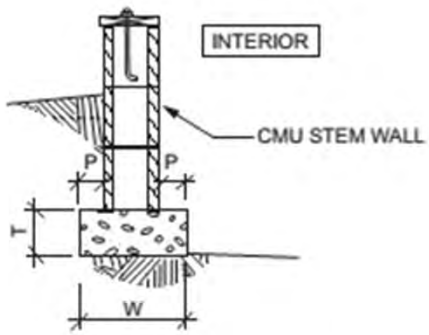

1 MONOLITHIC SLAB-ON-GROUND WITH TURNED-DOWN FOOTING
SCALE: NOT TO SCALE



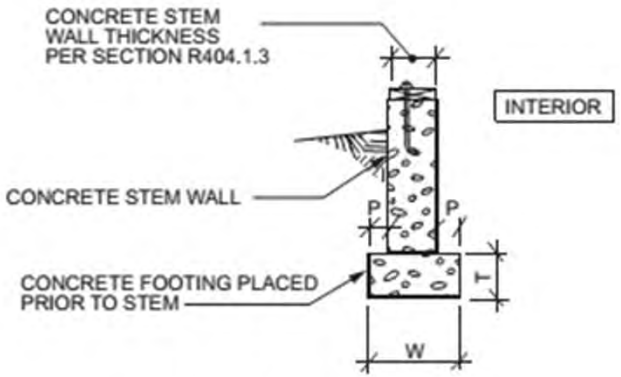

2 THICKENED SLAB-ON-GROUND FOOTING AT BEARING WALLS OR BRACED WALL LINES
SCALE: NOT TO SCALE



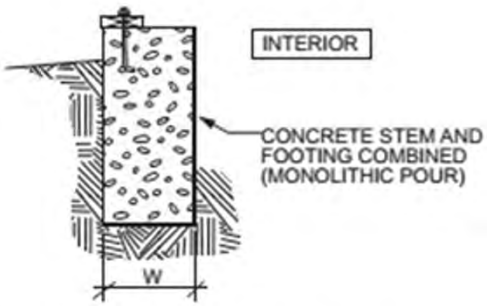

3 SLAB-ON-GROUND WITH MASONRY STEM WALL AND SPREAD FOOTING
SCALE: NOT TO SCALE




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



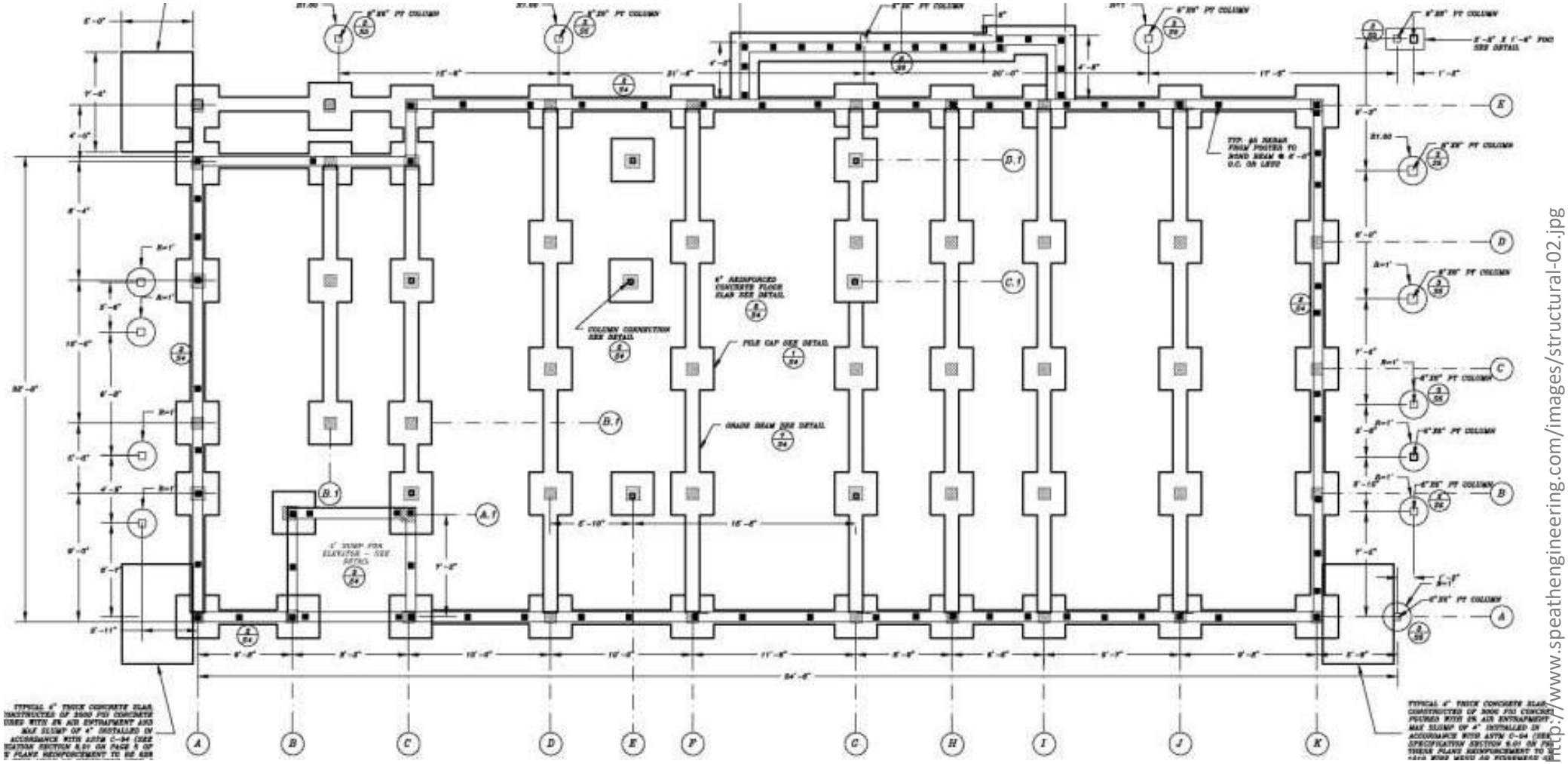

5 BASEMENT OR CRAWL SPACE WITH CONCRETE WALL AND SPREAD FOOTING
SCALE: NOT TO SCALE




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

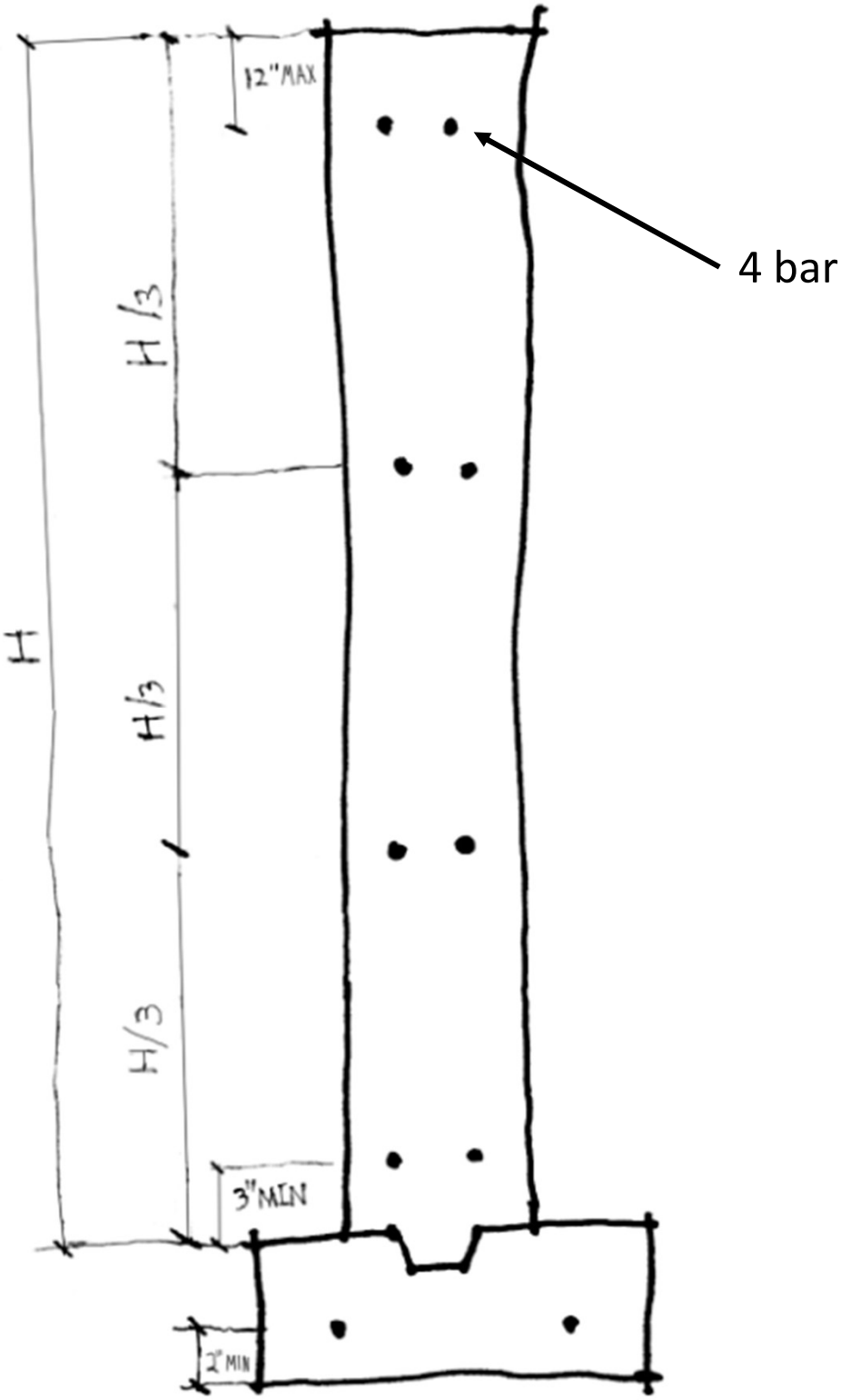

http://diygreenbuildingwithjerry.blogspot.com/2015/09/

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

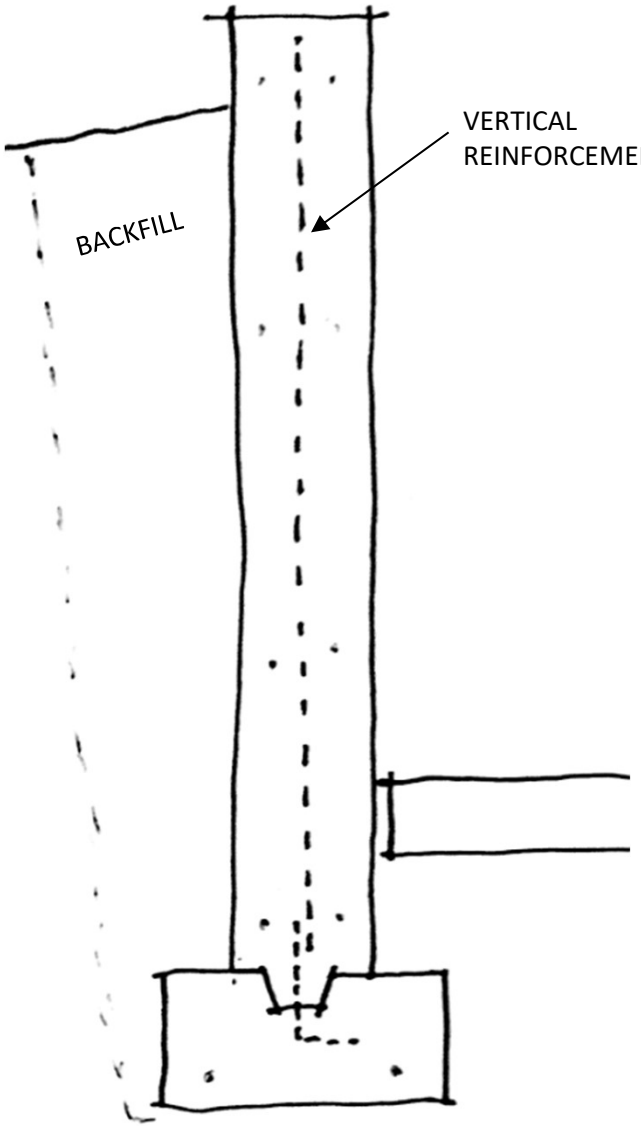
| MAXIMUM UNSUPPORTED HEIGHT OF BASEMENT WALL (feet) | LOCATION OF HORIZONTAL REINFORCEMENT |
|---|---|
| ≤ 8 | One No. 4 bar within 12 inches of the top of the wall story and one No. 4 bar near mid-height of the wall story. |
| > 8 | One No. 4 bar within 12 inches of the top of the wall story and one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




| 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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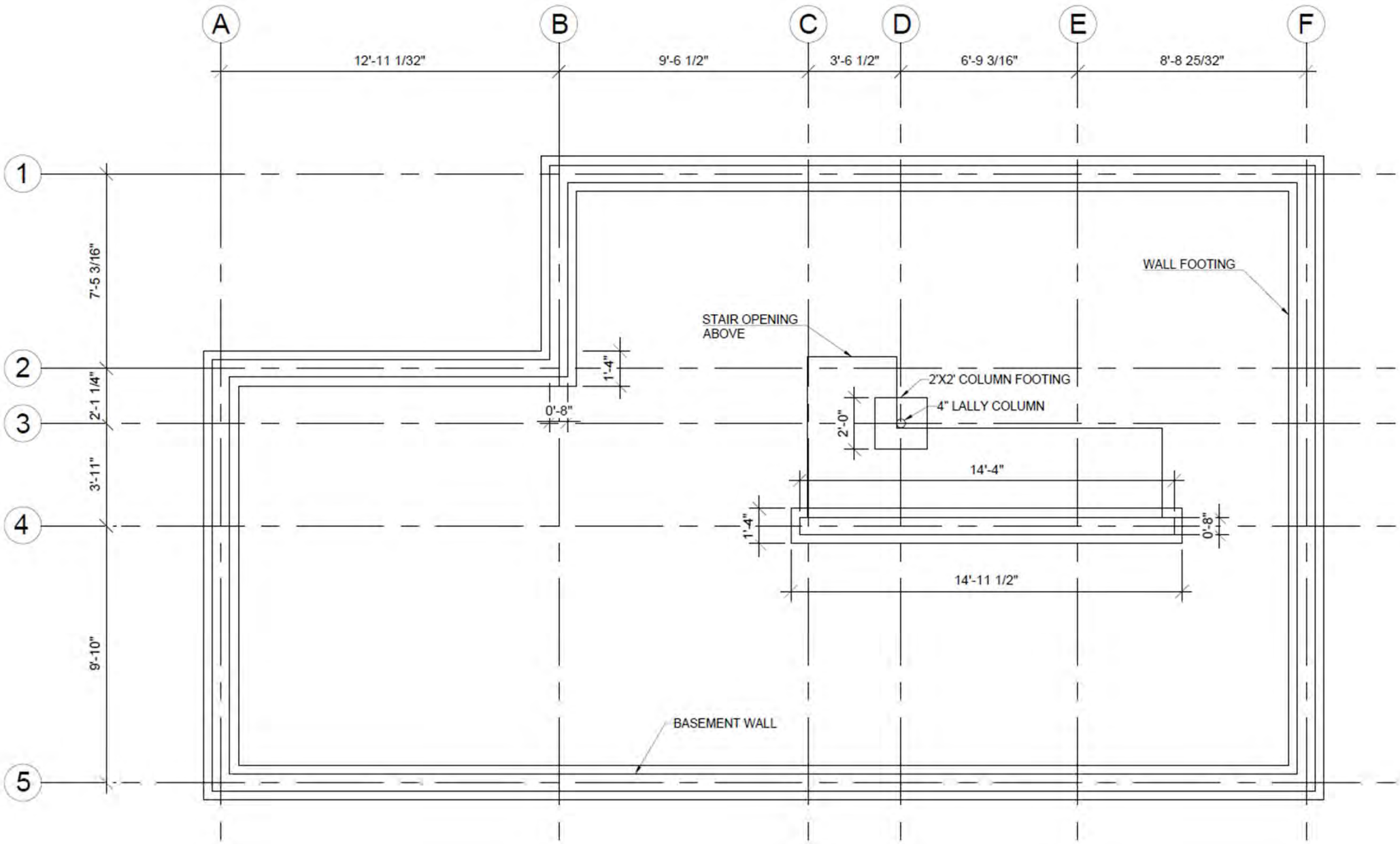
# FOOTING PLAN
(example)



# CELLAR PLAN
(example)