FOUNDATIONS

Liquefaction

Liquefaction reduces soil strength and stiffness by earthquakes shaking. Liquefaction caused great damage in past earthquakes.

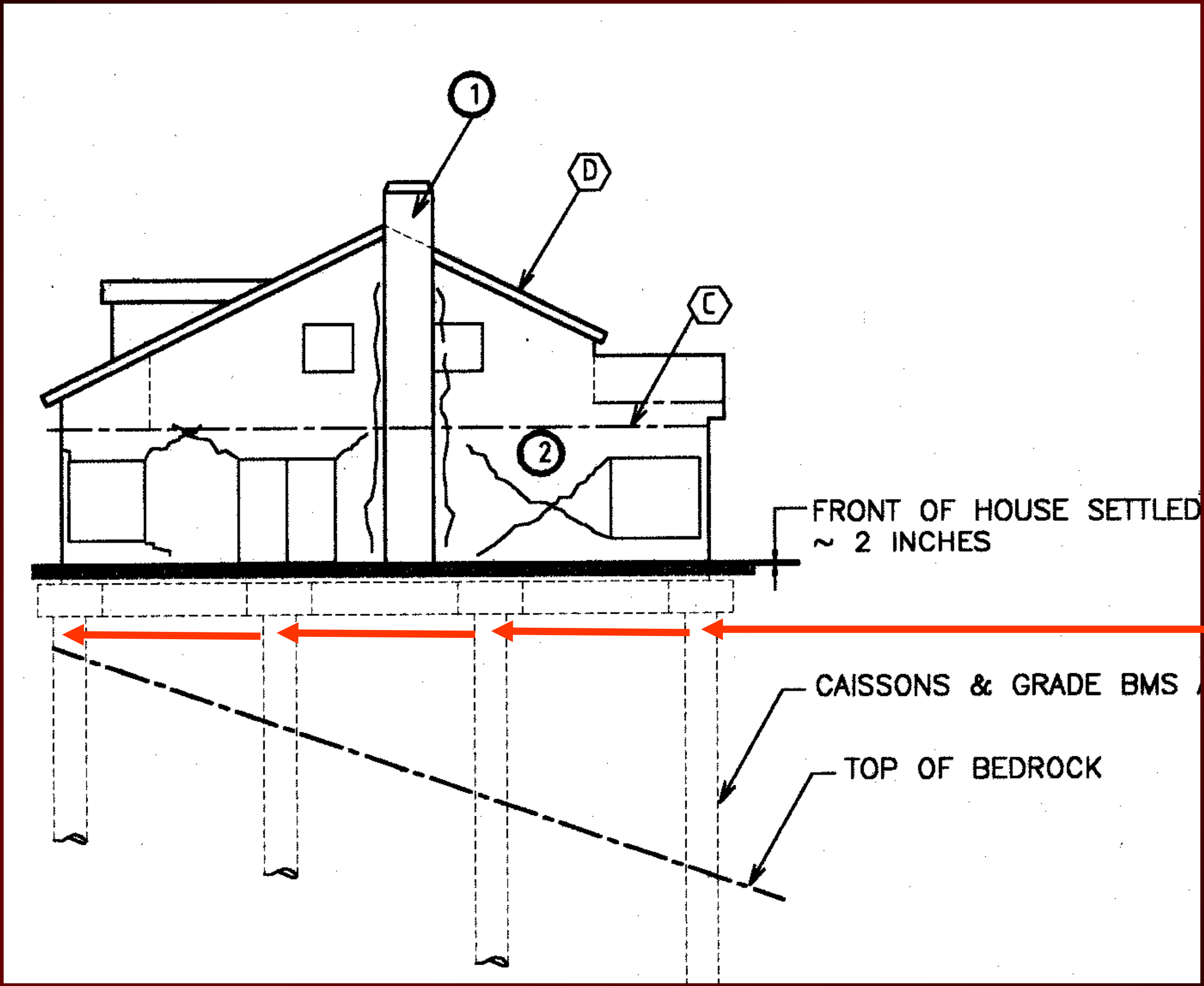
Liquefaction occurs in sandy soil saturated with water. Earthquakes increase the water pressure to make the soil liquid.

Landslide

Landslides are movements of surface material down a slope.
Landslides may be caused by earthquakes.

During a Northridge Earthquake aftershock landslide dust blows eerily out of the Santa Susana Mountains into the Simi Valley

Sustainable hill site design



To avoid expensive earthquake settlement repair ……

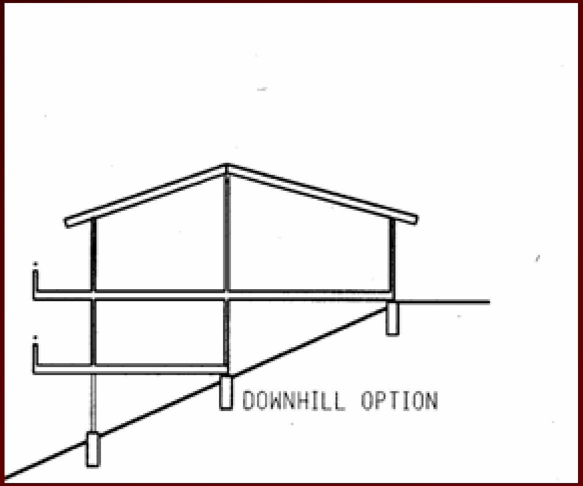
………. adapt buildings to site – instead of adapting site to buildings

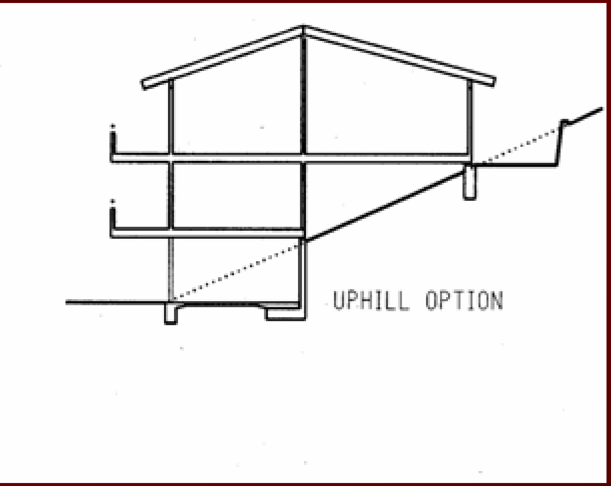
to reduces grading

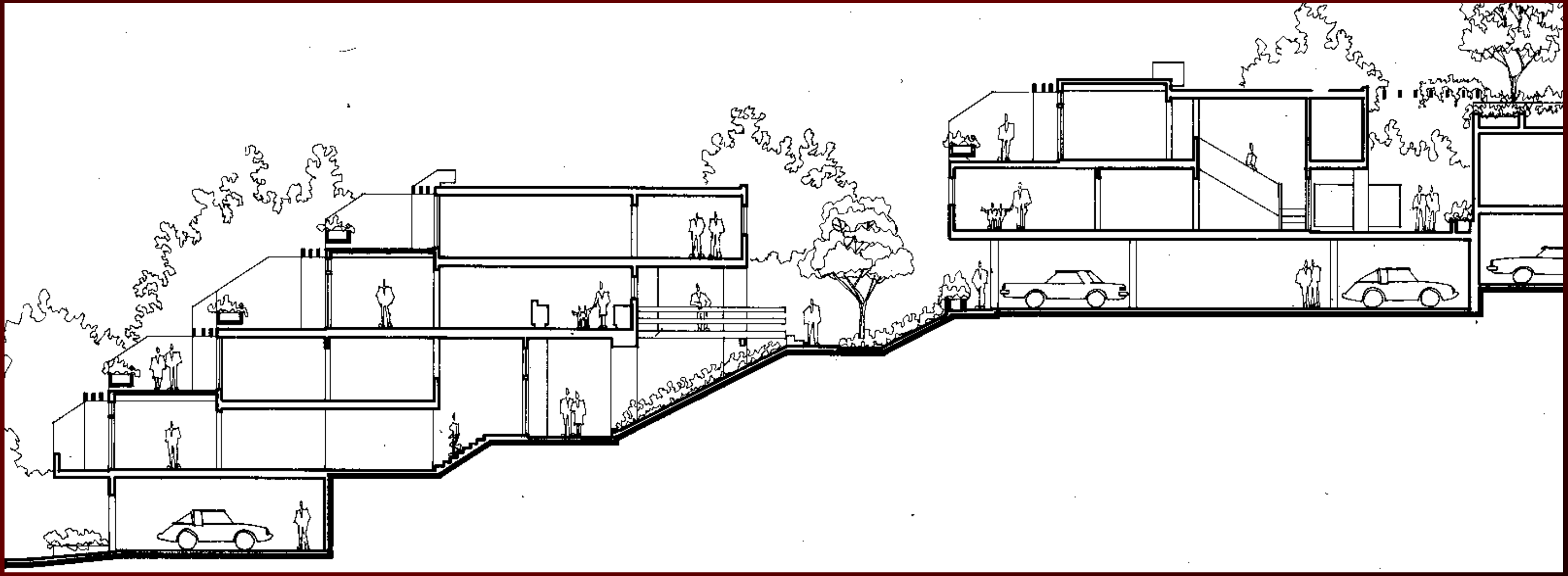
and retaining walls

and avoid expensive

settlement repairs ☺





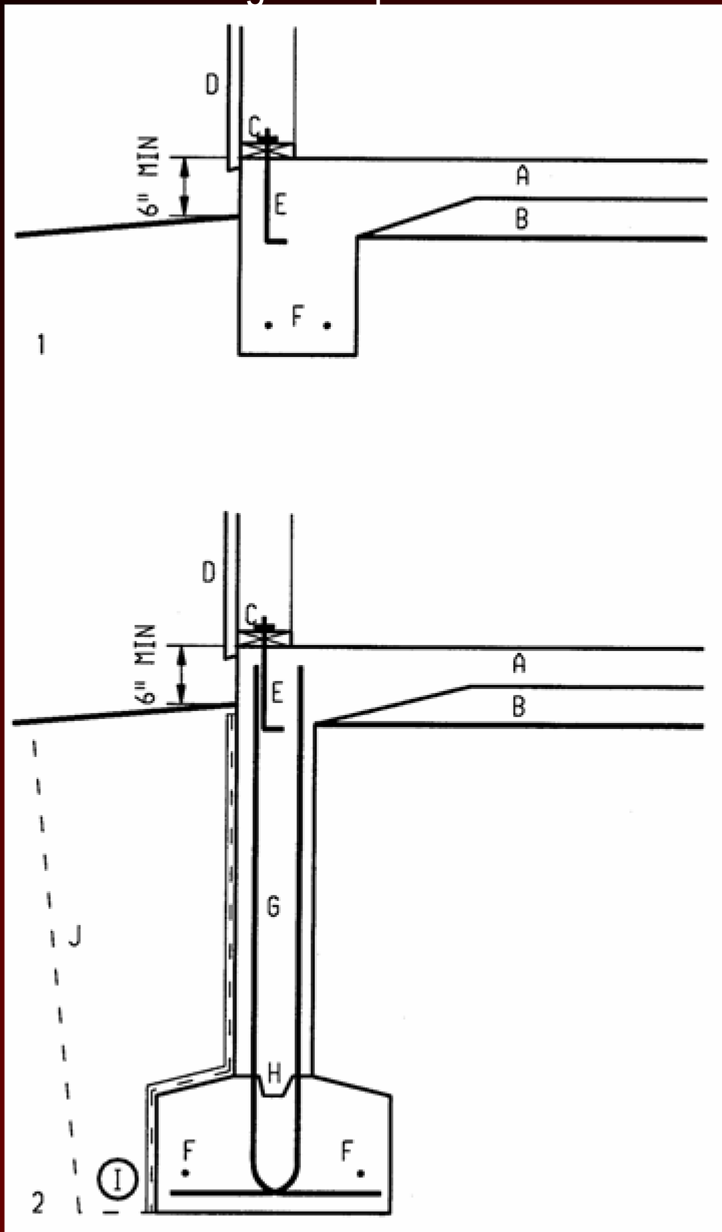


Soil Capacity

Soil type	Soil capacity (approximate)	
Soft clay	2 ksf	100 kPa
Stiff clay	4 ksf	200 kPa
Sand, compacted	6 ksf	300 kPa
Gravel	15 ksf	700 kPa
Sedimentary rock	50 ksf	2400 kPa
Hard rock (granite)	200 ksf	9600 kPa

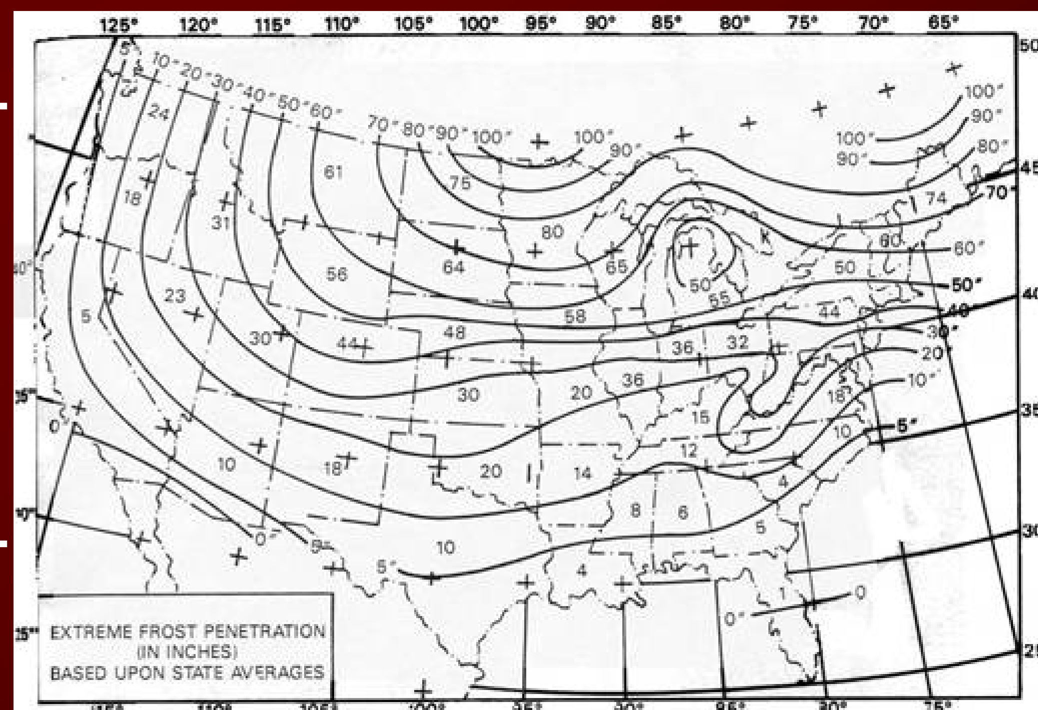
Footing depths

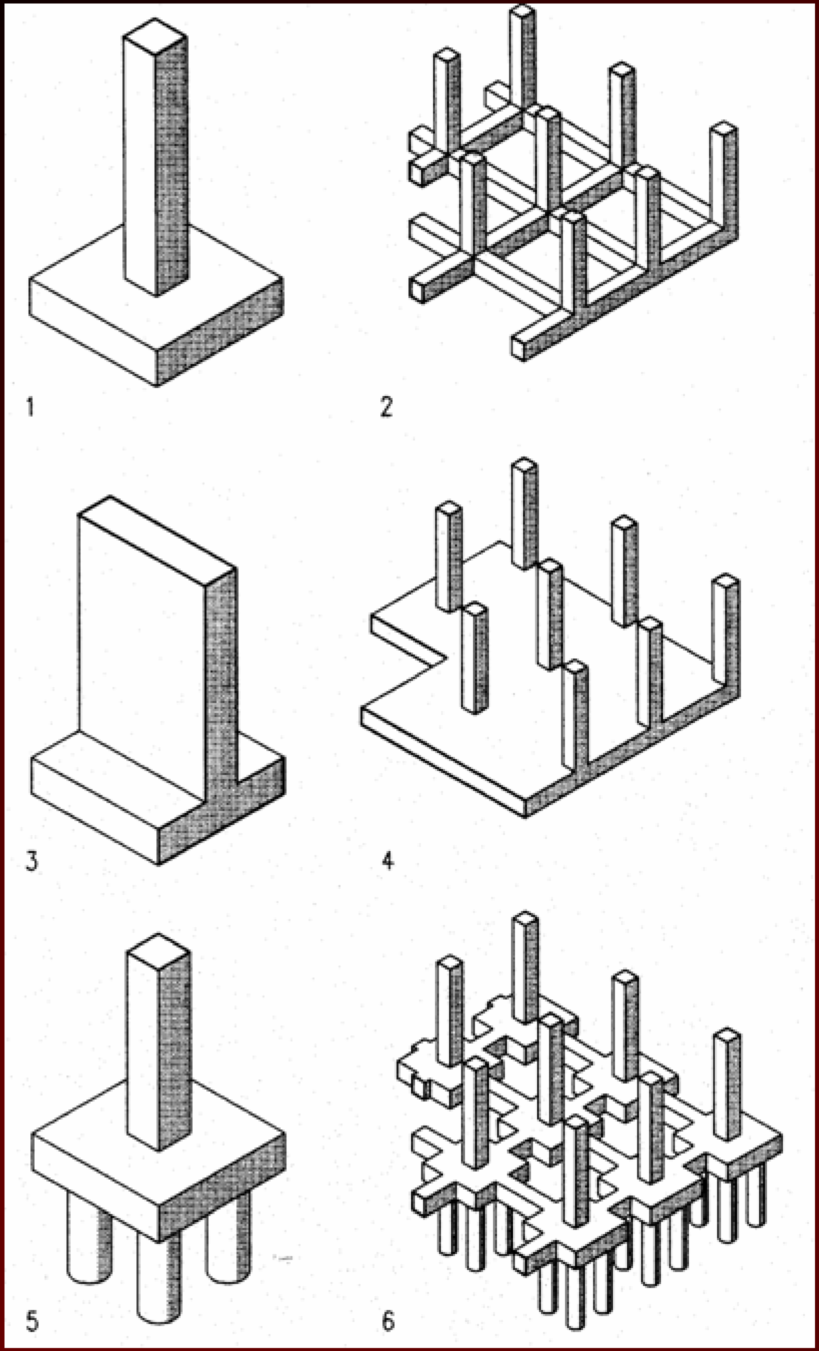
Wood framing example



1 Shallow footing (in areas of no frost)
2 Frost-free footing (depth per map below)
A Slab on grade, 4" with welded wire mesh (8" edge resists shear)
B Gravel bed and waterproof membrane
C Base plate, pressure treated, min 6" above grade
D Plywood sheathing
E Anchor bolts at max. 4' o. c.
F Footing rebars
G CMU stem wall with dowel bars & waterproof membrane
H Stem wall key
I Perforated drain pipe at base of footing
J Gravel bed

Frost penetration map





Footing types

1 Column footing

2 Grade beams

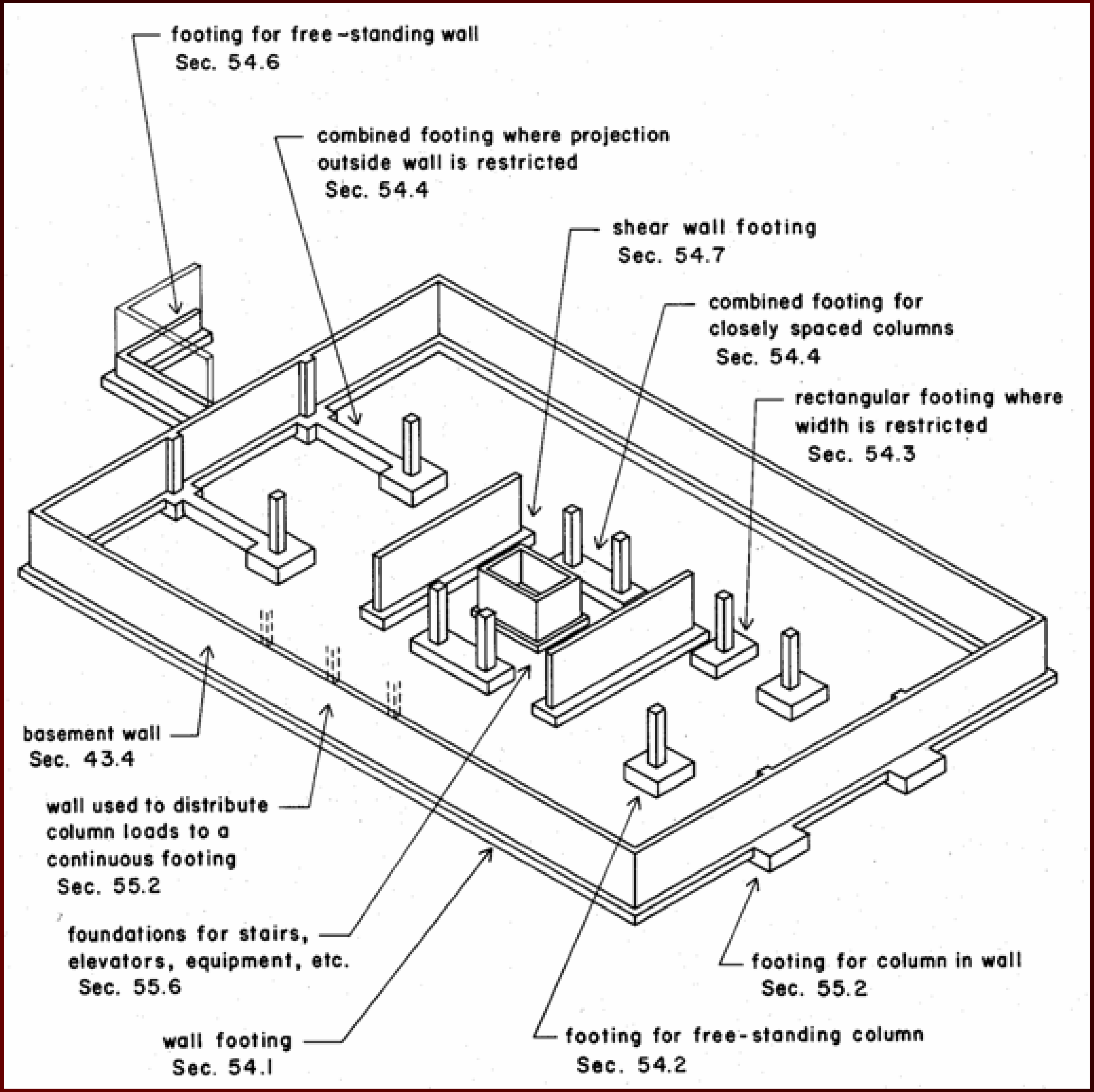
3 Wall footing

4 Mat footing

5 Piles (joint by pile caps to distribute load)

6 Grade beams join pile caps for lateral stability

Footing type use



Footing construction

Poor quality excavation causes poor footings

Formwork provides better quality

Stepped footing at sloping site

Reinforcing

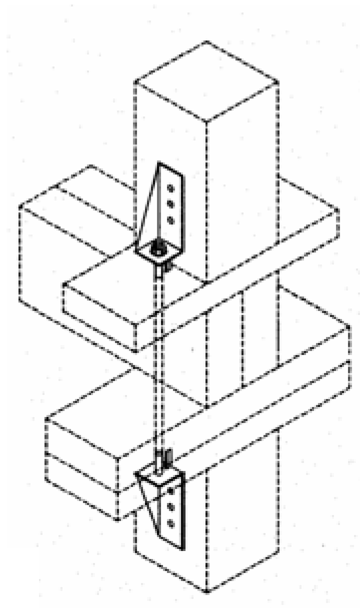
Post footings require 2-way reinforcing

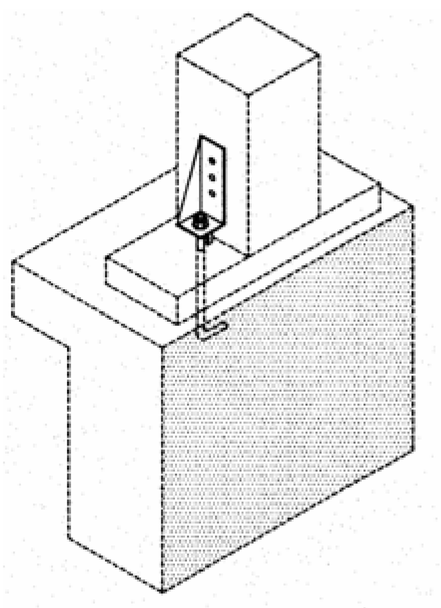
Wall footings require length reinforcing

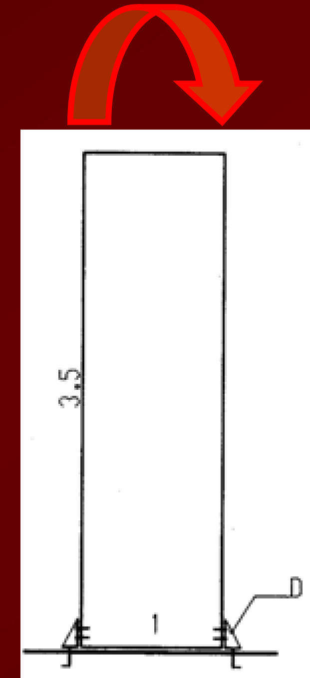
Wide wall footings require also width reinforcing

Concrete and CMU walls require dowel bars
(must overlap with wall bars 40 bar diameter)

Hold-down & post base





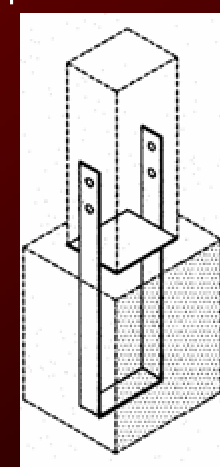


To resist overturning, wood shear walls require hold-downs at both sides

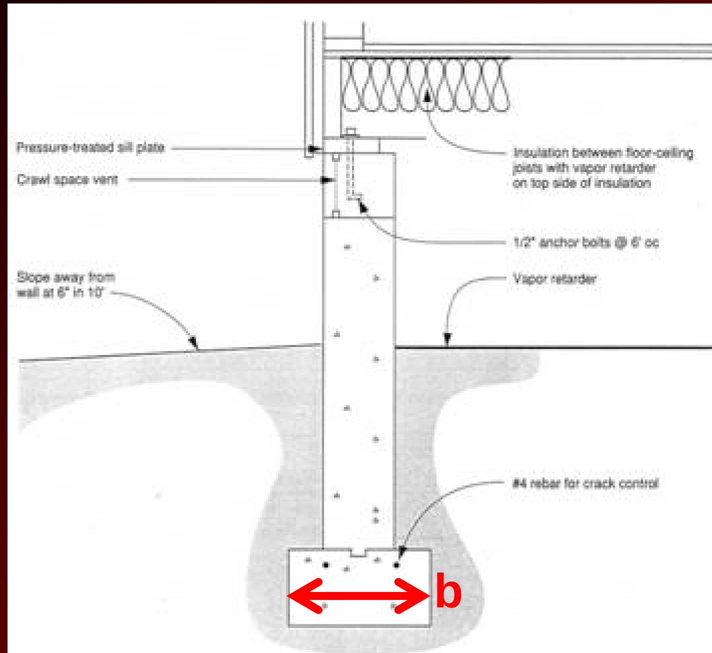
Twin hold-downs tie top wall to wall below

Hold-down ties wall to footing

Post base ties post to footing



Wall footing
With stem wall
and crawl space



Wall footing design

Assume:

Soil capacity

unknown, use code minimum f = 1500 psf

2-story wood framing

Floor load (incl. walls) DL = 25 psf

LL = 40 psf

Roof load (incl. walls) DL = 15 psf

<u>LL = 20 psf</u>

Total load Σ = 100 psf

Tributary width supported by wall

e = 20'/2 e = 10'

Wall load per foot

w = 100 psf x 10' w = 1000 plf

Footing DL estimate

(assume 8"x4' stem wall+1.5'x1' ftg.)

w = 150 pcf (1.5'x1'+4'x8"/12) w = 625 plf

Total load

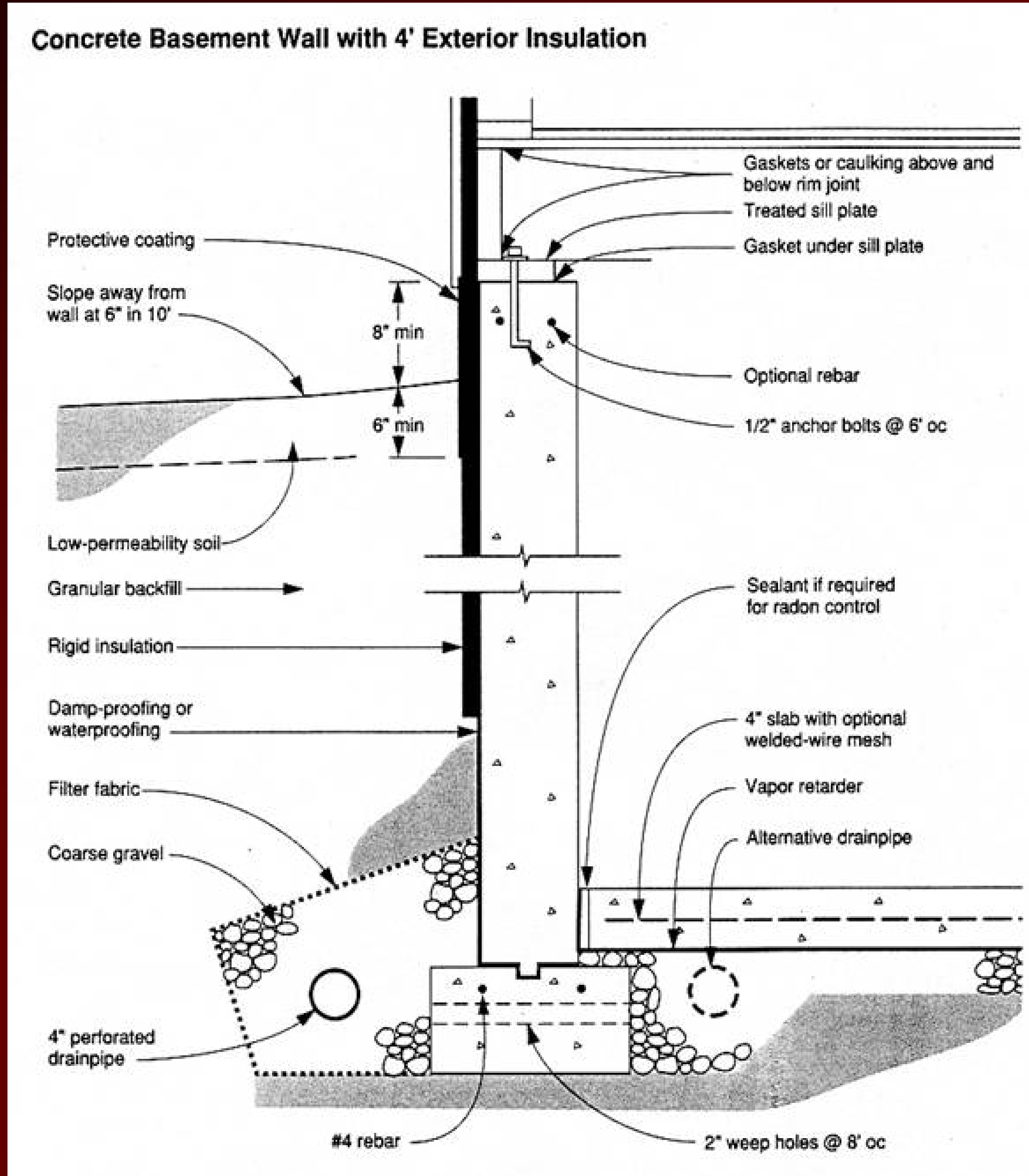
w = 1000+625 w = 1625 plf

Required footing width

b = w/f = 1625/1500 = 1.1' use b = 18"

Basement wall

Concrete or CMU (cost less)



Note: if great frost depth is required, basements are cost-effective

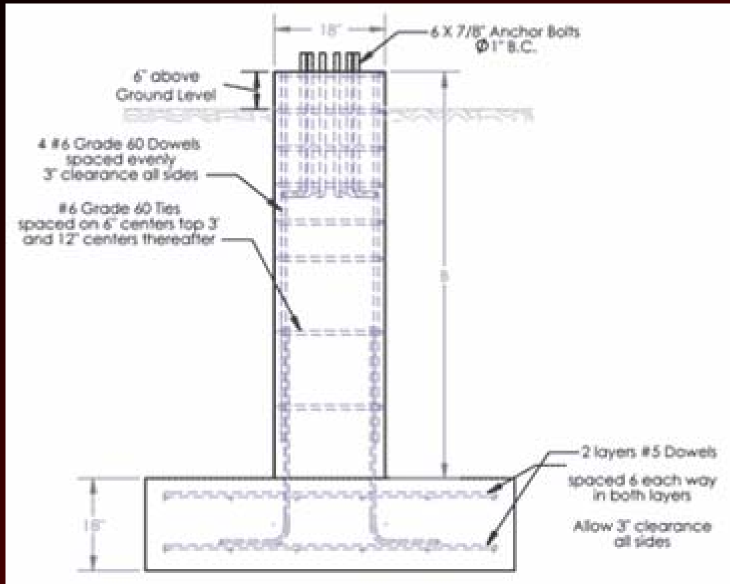
Concrete wall footing design

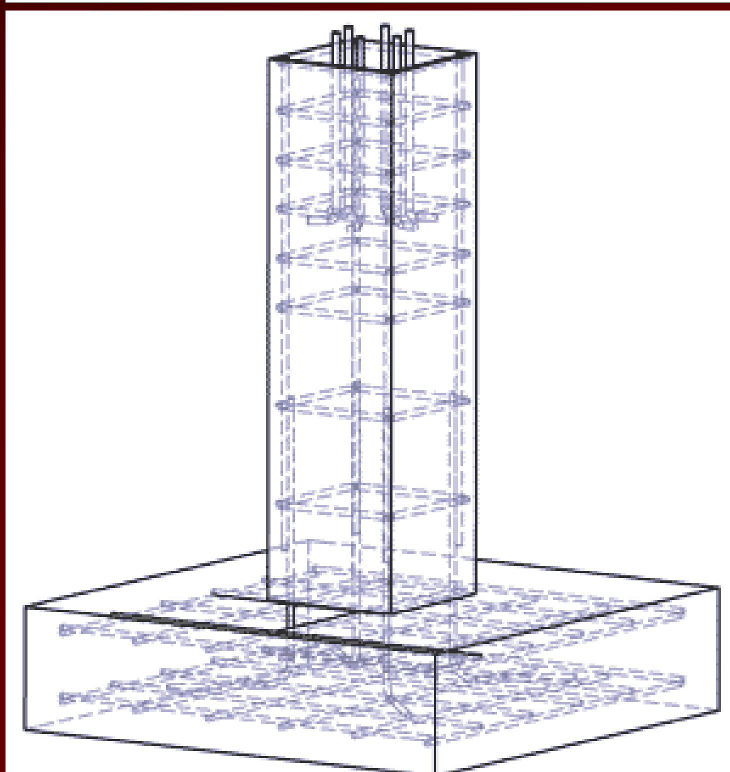
Assume:

Soil capacity

Soft clay	f = 2000 psf
2-story concrete	
Floor load (incl. walls)	DL = 170 psf
	LL = 50 psf
Roof load (incl. walls)	DL = 120 psf
	LL = 20 psf
Total load	Σ = 360 psf

Tributary width supported by wall	
e = 20'/2	e = 10'
Wall load per foot	
w = 360 psf x 10'	w = 3,600 plf
Footing DL estimate	
(12" basement wall, 9' high)	
w = 150 pcf (3'x1.5'+1'x9')	w = 2,025 plf
Total load	
w = 3,600+2,025	w = 5,625 plf
Required footing width	
b = w/f = 5,625/2000 = 2.8'	use b = 3'





Post footing Design

Assume:

2-story building

Soil capacity (stiff clay) $f = 4$ ksf

Loads: 150 psf DL + 50 psf LL $\Sigma = 200$ psf

Tributary area

A = 30'x30' $A = 900\ ft^2$

Post load

P = 2x200x900/1000 P = 360 k

Footing DL (estimate 10x10'x18")

P = 10'x10'x1.5'x150 pcf/1000 P = 23 k

Required Footing area

$A_f = P/f = (360+23)/4$ ksf $A_f = 96\ ft^2$

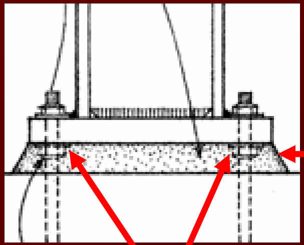
Footing size

$b = A_f^{1/2} = 96^{1/2} = 9.8'$ use 10'x10'x18"

Steel column base

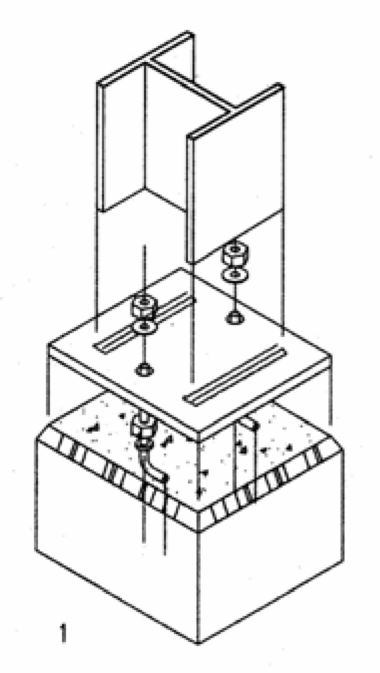
Post template with anchor bolts, furnished by steel fabricator, installed in concrete footing

Post with base plate, replacing template, attached to anchor bolts



Grouting

Twin nuts to align post prior to grouting



Steel erection

Construction steps:

1 Excavate

Construction steps:

2 Place reinforcing

Dowel bars must overlap post/wall bars minimum 40 bar diameters

Construction steps:

3 Place concrete

Mat footing

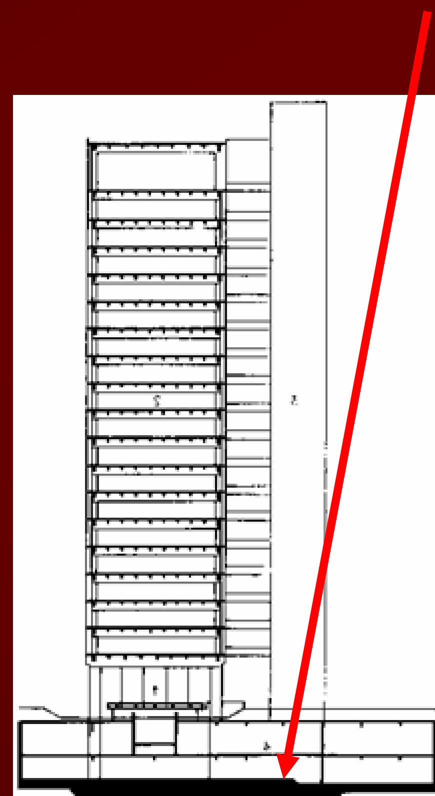
Crown Zellerbach building, San Francisco

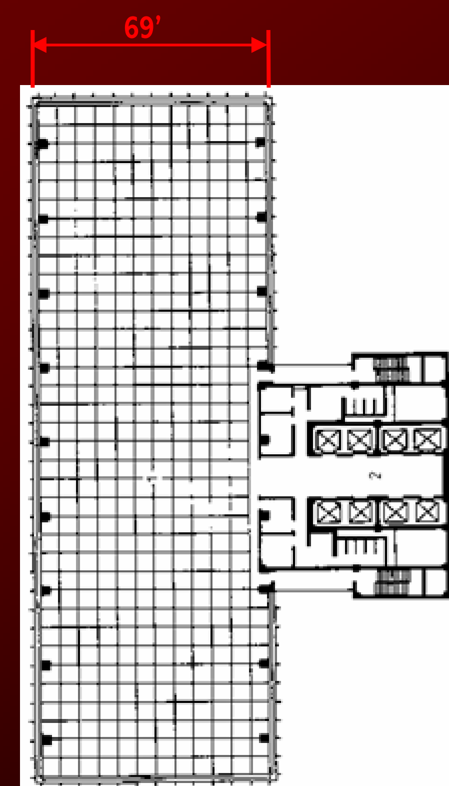
Architect: SOM with Hertzka and Knowles
Engineer: H J Brunnier

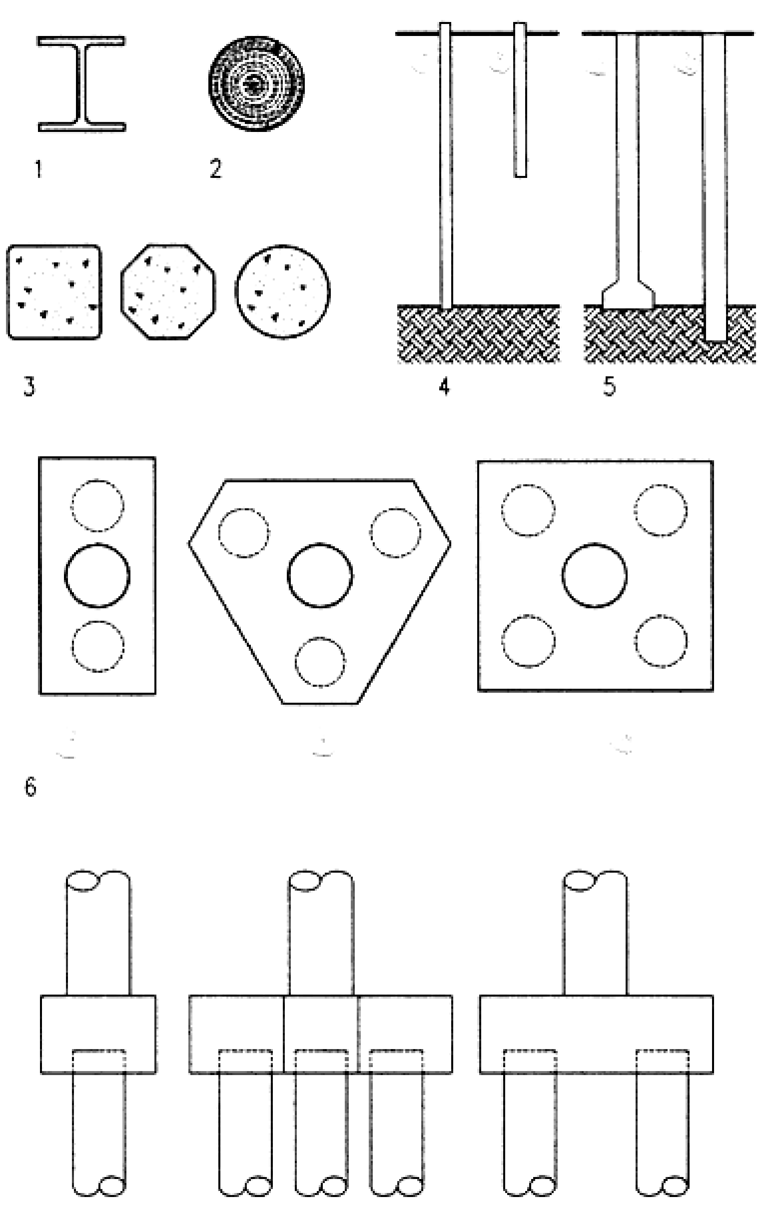
The 19-story building has a mat footing that extends under the entire building to resist ground water buoyancy during construction

Building height: 285'

Footing depth: 8'







Pile and caisson

Piles and caissons/piers are used in poor soil to increase bearing capacity

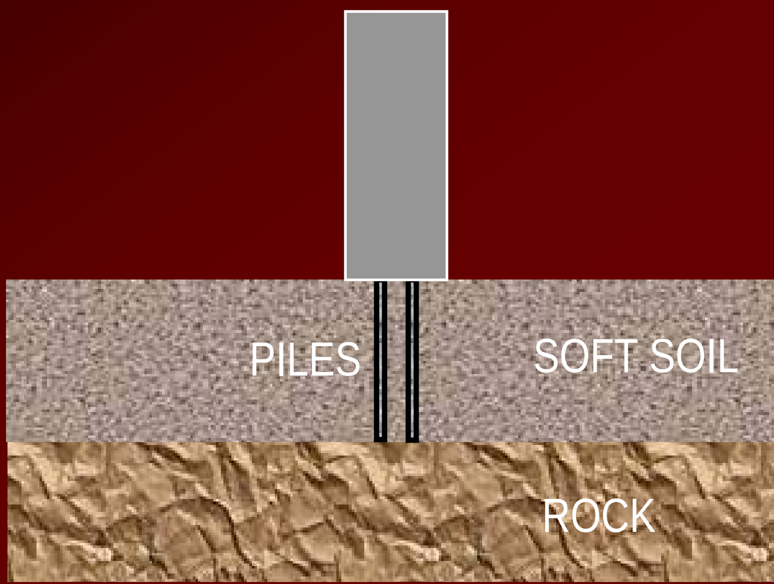
Piles are driven into soil
Caissons/piers are cast into shafts that are excavated or drilled

1 Steel H-pile
2 Timber pile
3 Concrete piles
4 Piles
Left: end-bearing pile
Right: friction pile
5 Caissons/piers
Left: Caisson with bell to increase bearing
Right: straight caisson
6 Pile caps

Pile types

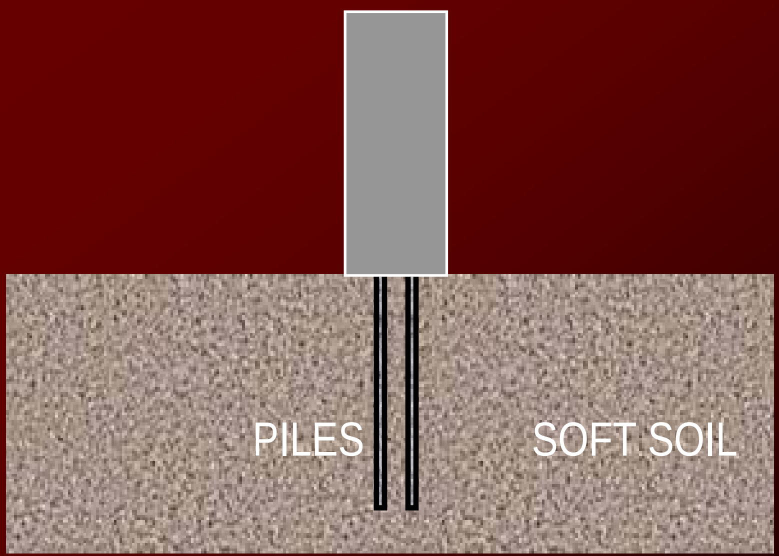
End Bearing Piles

End bearing pile transmit load through soft soil to rest on firm soil or rock



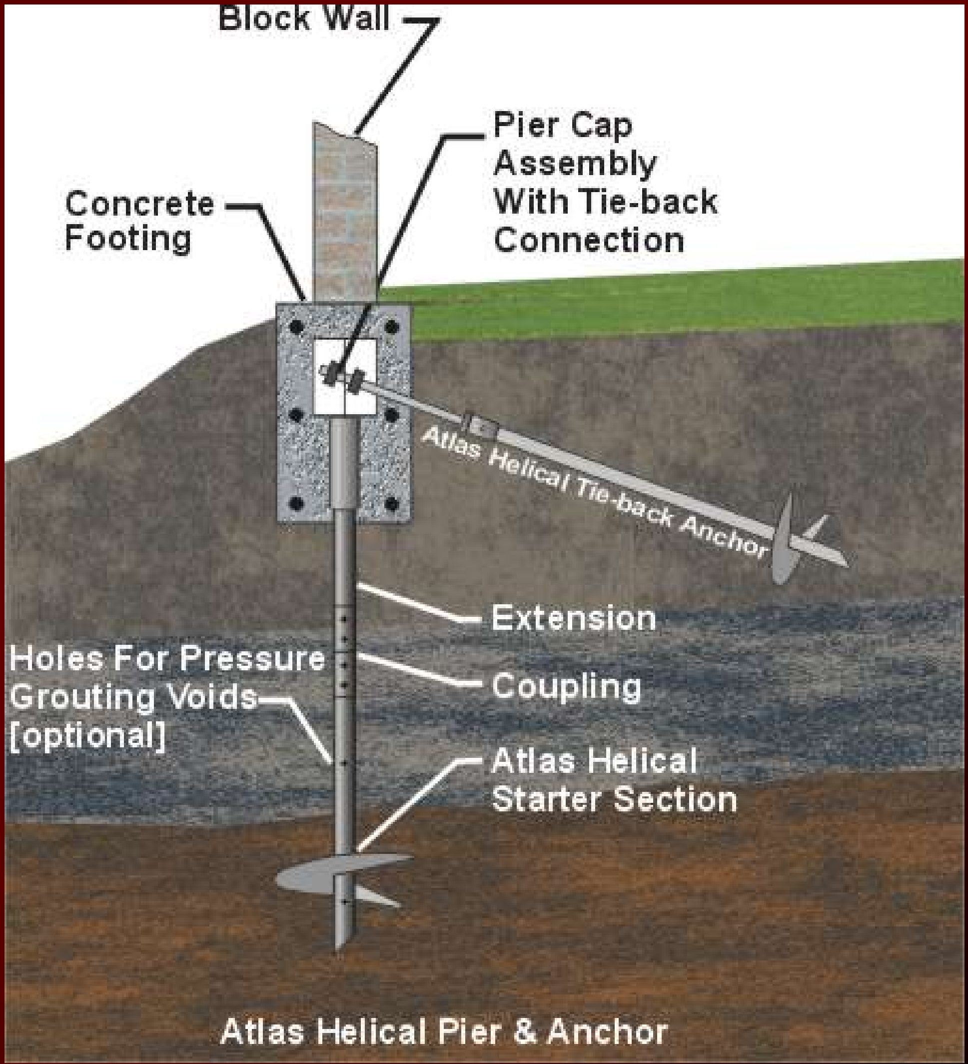
Friction Piles

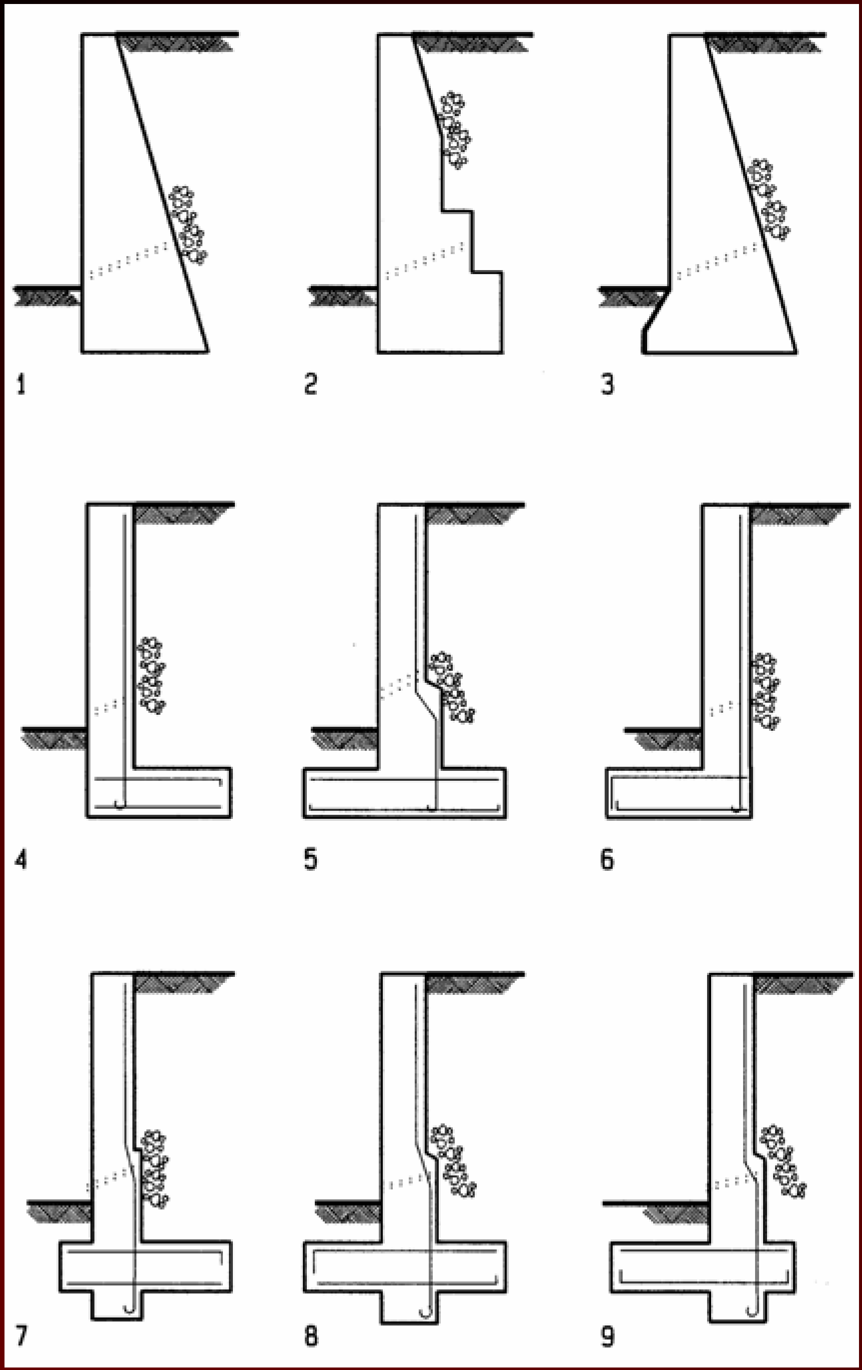
If firm soil is too deep, friction piles resist load by friction between pile and soil



Pile driving

Cason/pier drilling





Retaining walls

1-3 Mass retaining walls

4 Concrete / CMU wall at property line with adjacent land lower

5 Concrete / CMU wall

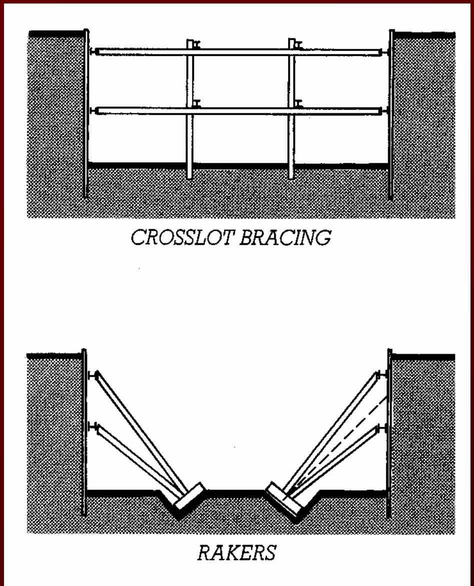
6 Concrete / CMU wall at property line with adjacent land higher

7 Concrete / CMU wall with shear key

8 Concrete / CMU wall with shear key

9 Concrete / CMU wall with shear key

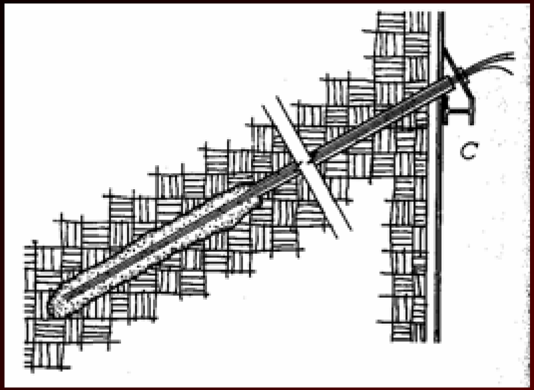
Note: shear key adds lateral resistance

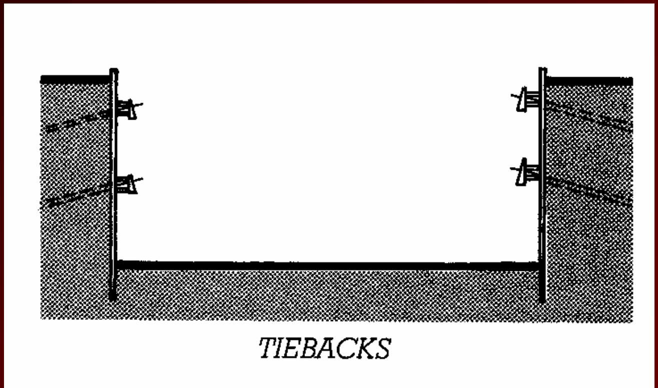


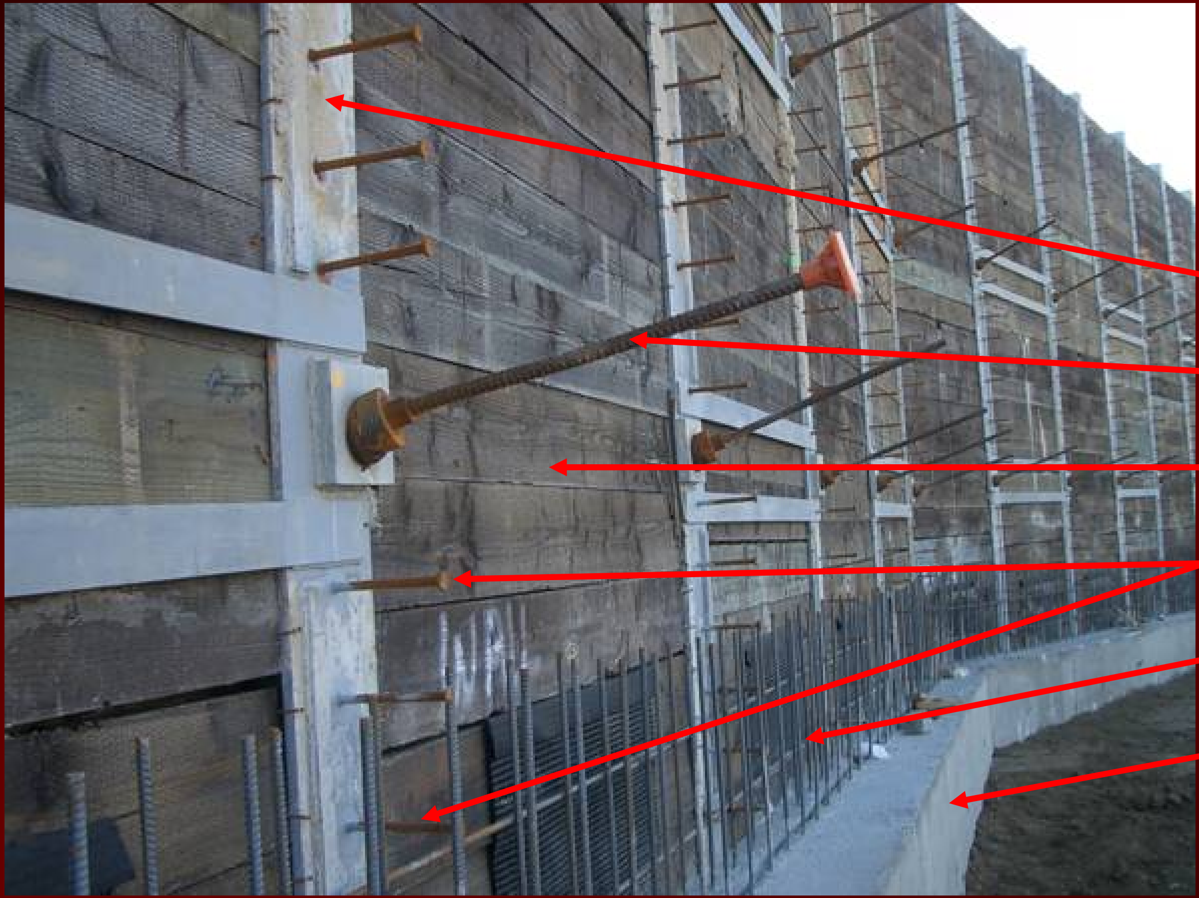
Floor bracing

Temporary bracing

Retaining wall with tiebacks







H-shape steel piling

Tiebacks anchor wall to soil

Wood boards

Bolts tie concrete wall to piling

Dowel bars tie concrete to footing

Footing

Tie-back

Installation

Prestressing
with hydraulic jack

Slot cutting

Used for retaining walls at property line

Slot cutting steps:

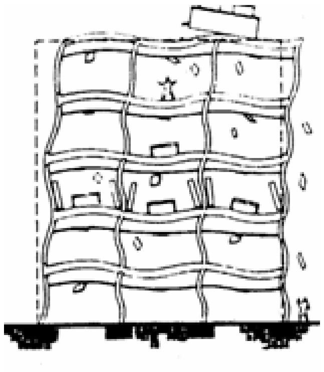
1 Cut slots in retaining slopes

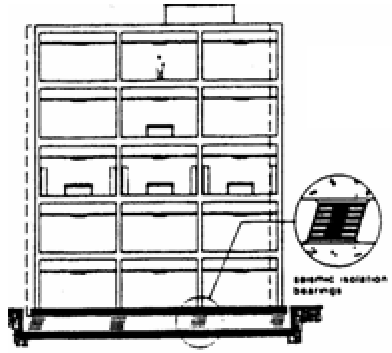
2 Build retaining wall segments

3 Backfill retaining walls after about a week (backfill adds soil pressure)

4 Cut soil between wall segments

5 Construct infill retaining walls

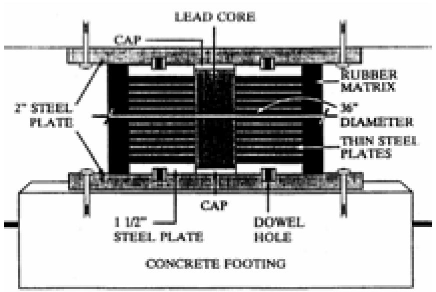


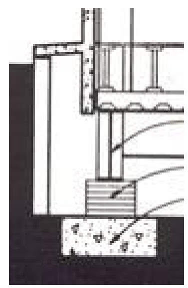


Base Isolators

Base isolators dampen seismic load, similar to the effect of shock absorbers on cars

Base isolators reduce differential building drift





Base isolators consist of rubber and steel sheets tied together by a central bolt and lead cylinder

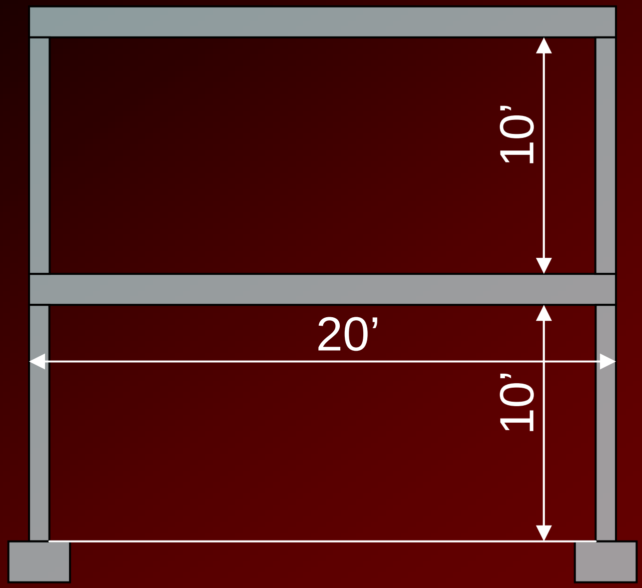
Buildings with base isolators must be isolated from surrounding ground to allow free movement

Base isolators are effective for low-rise buildings but increase overturn tendency of tall buildings

Base isolators are placed between footing and columns or walls

Kerckhoff Hall UCLA, base isolator upgrade
Courtesy WWCOT Architects


END



Exercise   Name:__________________

Assume: Concrete wall footing

Soil capacity	f_s = 2000 psf
Floor load (incl. walls)	DL = 140 psf
	LL = 50 psf
Roof load (incl. walls)	DL = 140 psf
	LL = 20 psf
Total load	Σ = 350 psf

Load on footing

w =   w =   plf

Footing DL estimate

w=150 pcf (2’x1.5’)   w =   plf

Total load

w =   w =   plf

Required footing width

b = w/f_s=   Use b =____ft