# Seismic Retrofit Training



# Focus

- How retrofit methods work
- How to install them
- Avoiding typical errors
- Learn to implement a ~~re~~retrofit NOT to design one

# Who Benefits?

- Contractors
- Realtors
- Building Inspectors
- Lenders
- Plan Reviewers
- Construction Attorneys
- Property Owners

# Objectives

- How earthquake shaking damages wood frame structures
- Key components of a retrofit
  - shear walls
  - hold downs
  - foundation
  - connections
- Installation steps for each component

# Objectives

- Typical errors
- Reducing hazards of structural features
- Basic health & safety measures
- Recognizing areas of potential liability
- Building permit requirements, warranties, and liabilities

# Why Retrofit?

- Safety
- Prevent loss of rental income
- Insurance requirements
- Municipal mandate
- Real estate disclosure

# Retrofit Contractors are in Demand

- Northridge in 1995:

  48,000 housing units uninhabitable

- Loma Prieta in 1989:

  16,000 housing units uninhabitable

## New House:

- Engineer or architect design

**OR**

- Conventional construction provisions of UB

## Retrofit:

- Engineer or architect design

**OR**

- Prescriptive standard

# Typical Simple Structure House



# Hillside Homes Require Professional Design

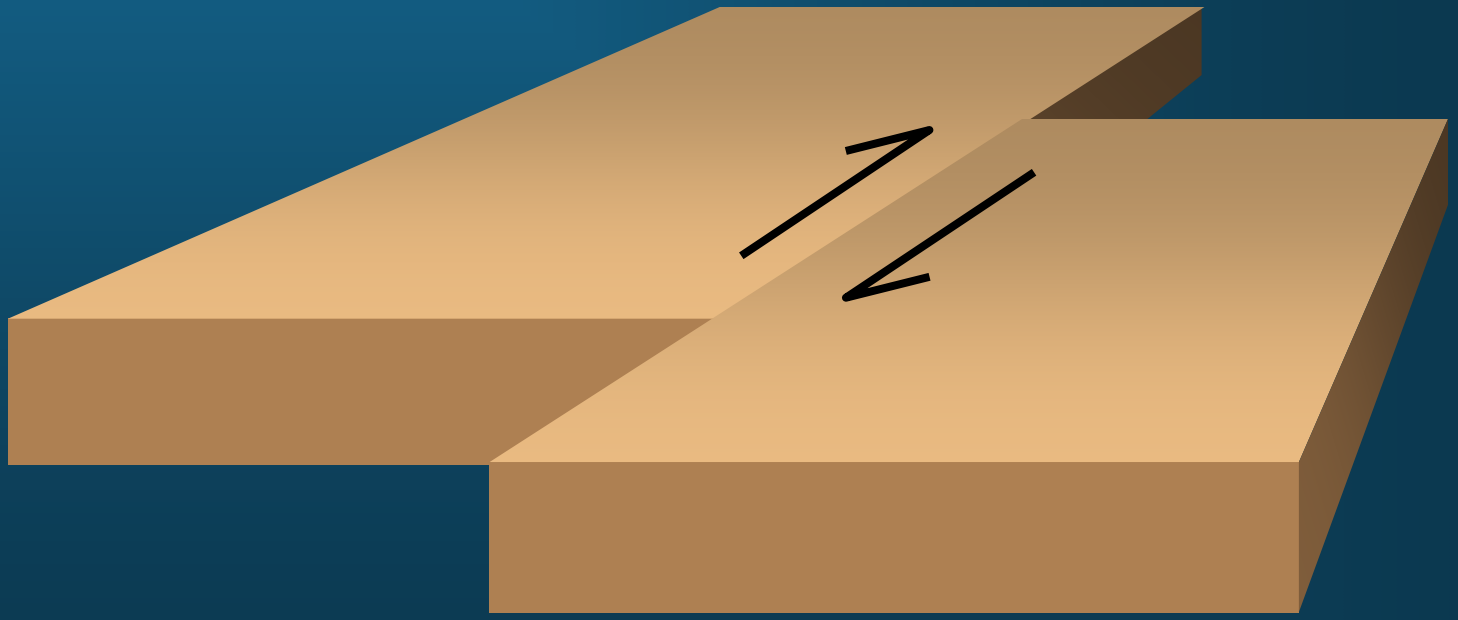


# Earthquake Basics

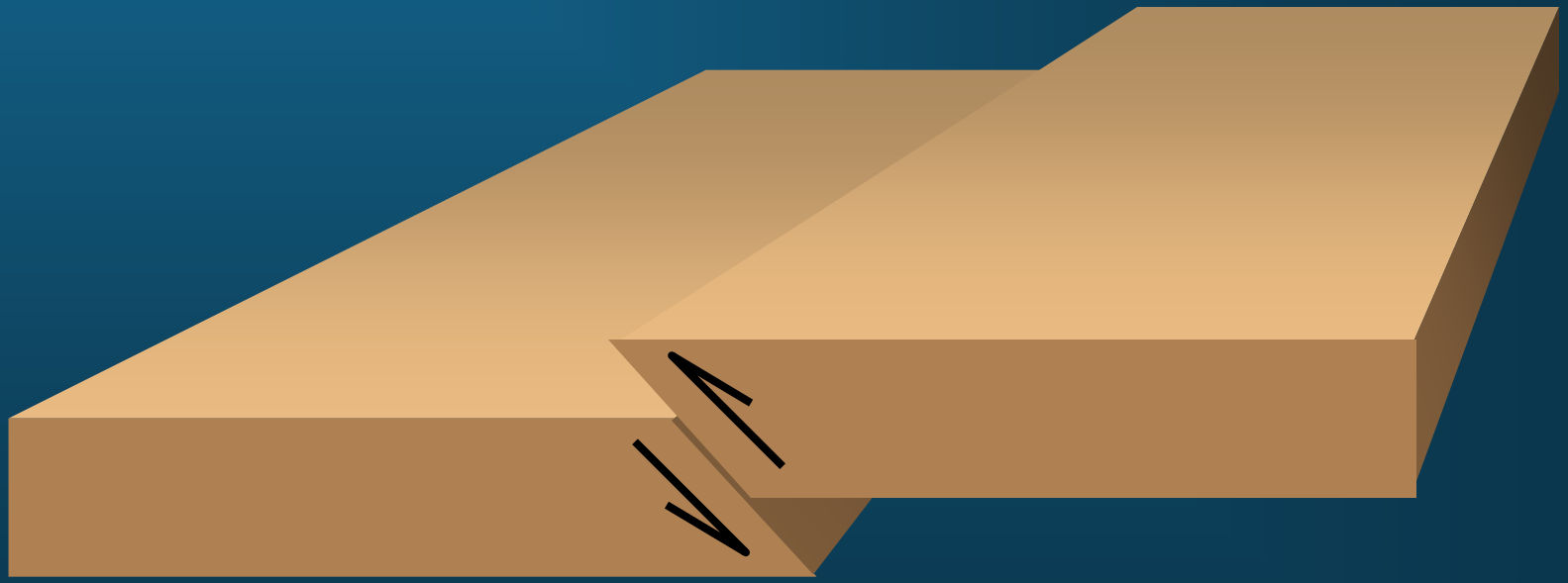
## Section 2

- What causes earthquakes?
- How do earthquake forces enter buildings?
- How does the building respond?
- What building elements resist forces?

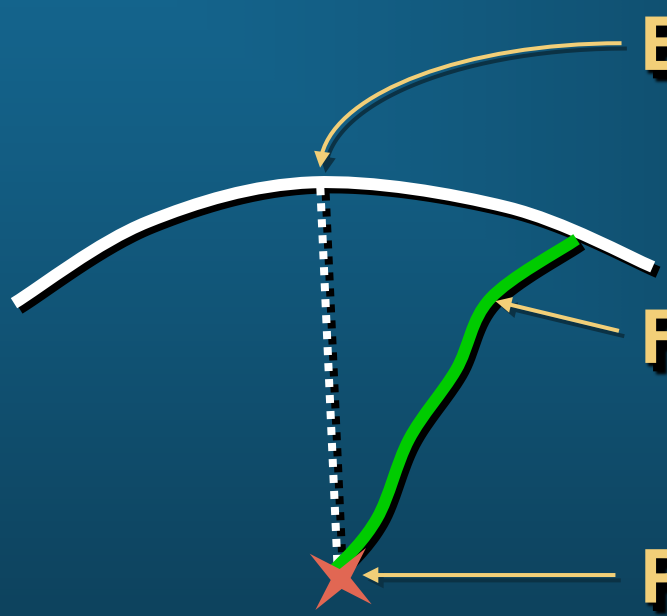
# Strike-Slip Fault



# Thrust Fault




Major Plates of the World
NORTH AMERICAN PLATE
EURASIAN PLATE
Basin and Range Province
San Andreas Fault
Gulf of California
COCOS PLATE
CARIB PLATE
ARABIAN PLATE
AFRICAN PLATE
PACIFIC PLATE
NAZCA PLATE
SOUTH AMERICAN PLATE
INDIAN-AUSTRALIAN PLATE
ANTARCTIC PLATE
SCOTIA PL
Himalayas
Java Trench
Atlantic
Ridge
Mid
Andes
Mountains
East
Pacific
Rise

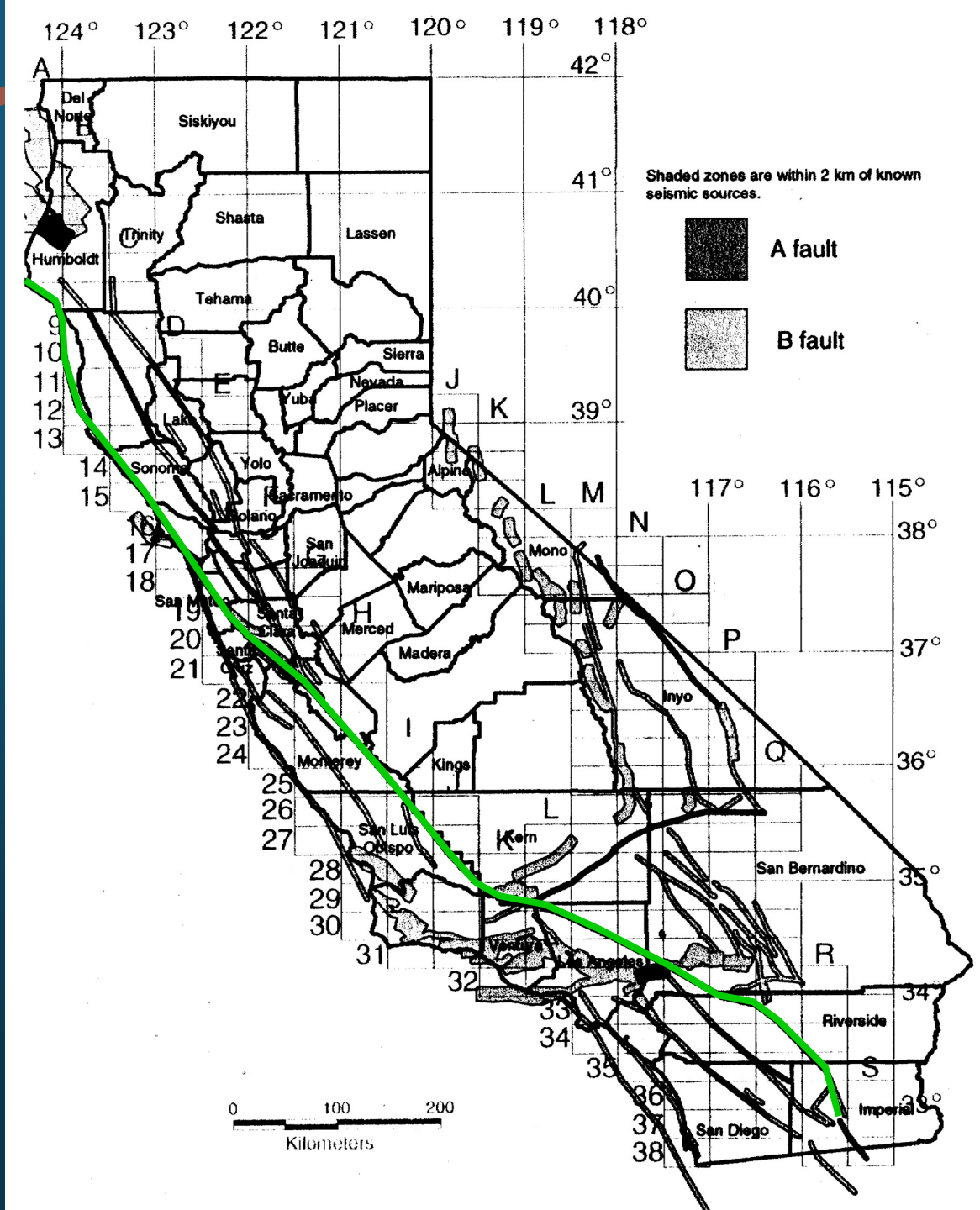


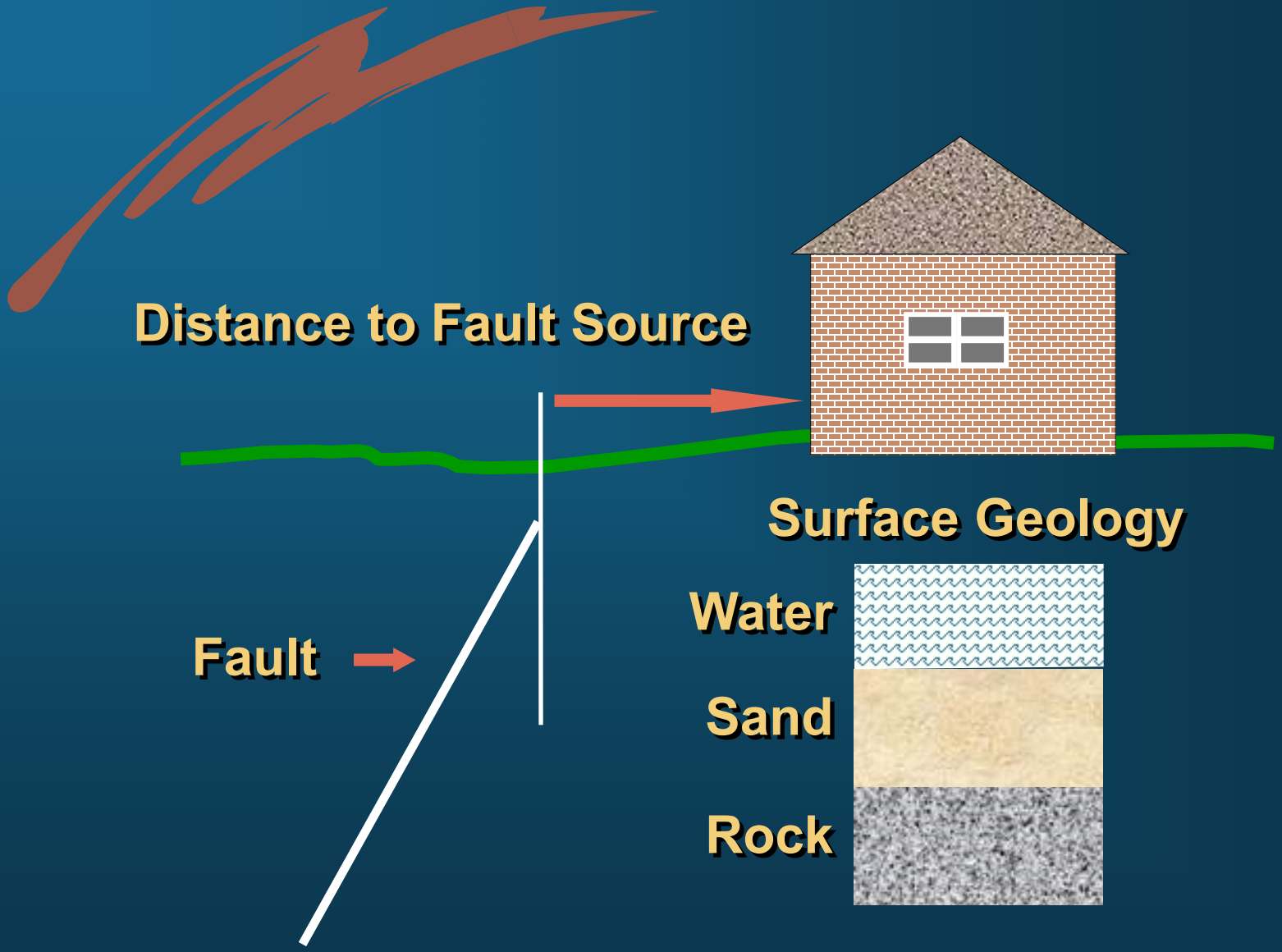
Epicenter

Fault

Point of fracture or slippage, termed Focus or Hypocenter

# California Index Map




Distance to Fault Source
Surface Geology
Water
Sand
Rock
Fault

# Liquefaction Failure



# Inertia Forces

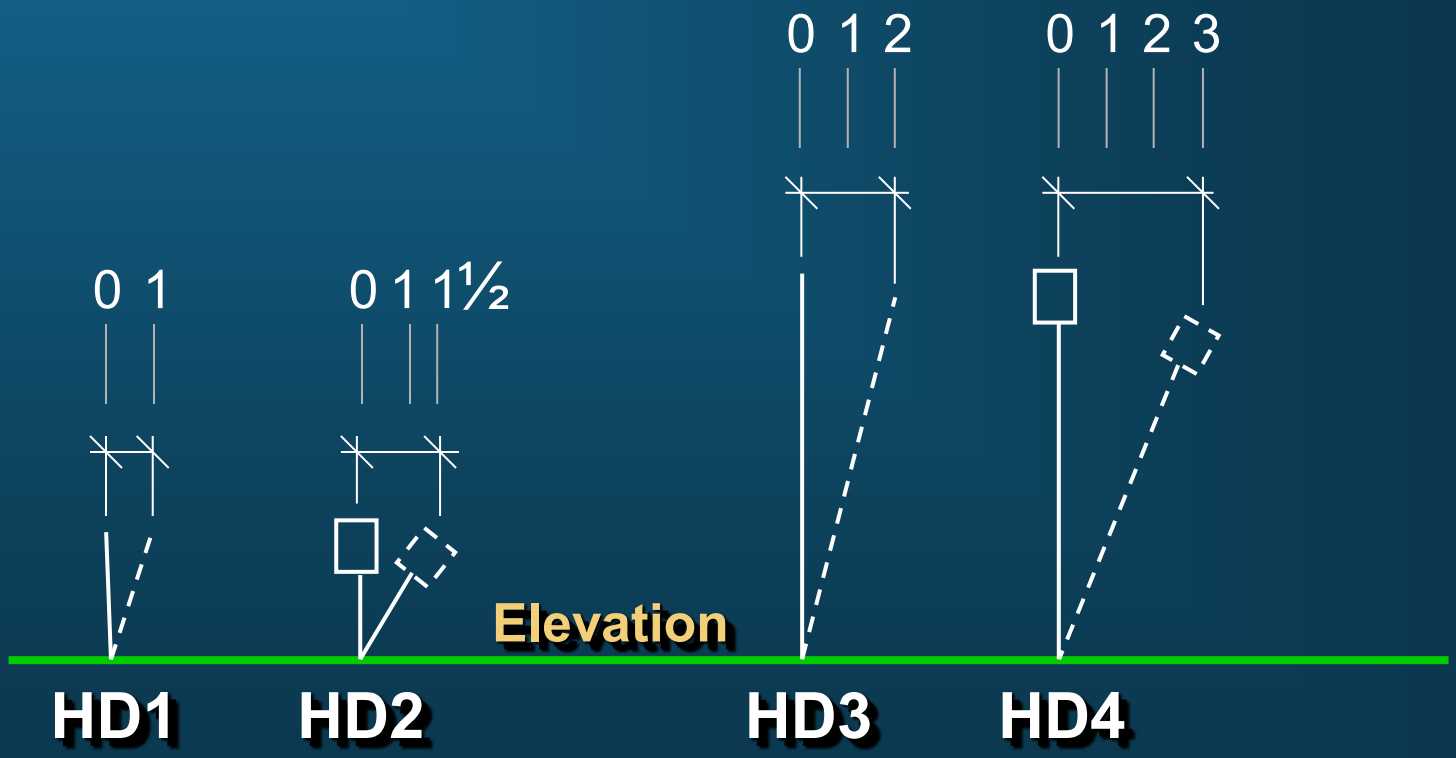


ACCELERATION

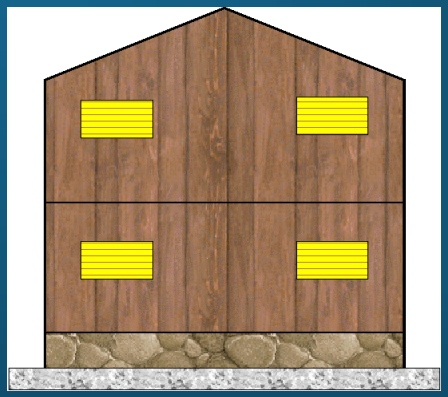


DECELERATION

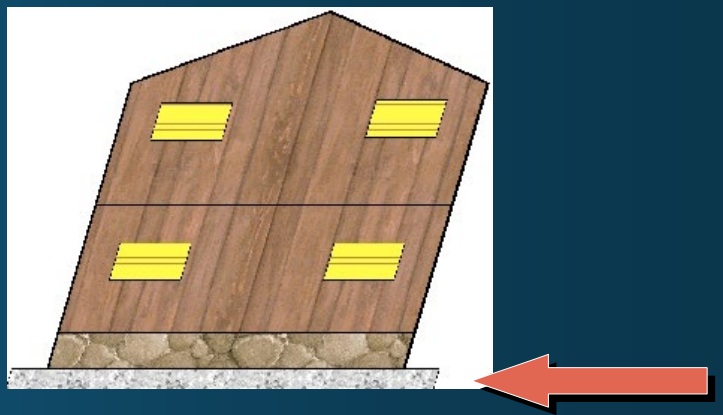
# Height / Weight Relationship



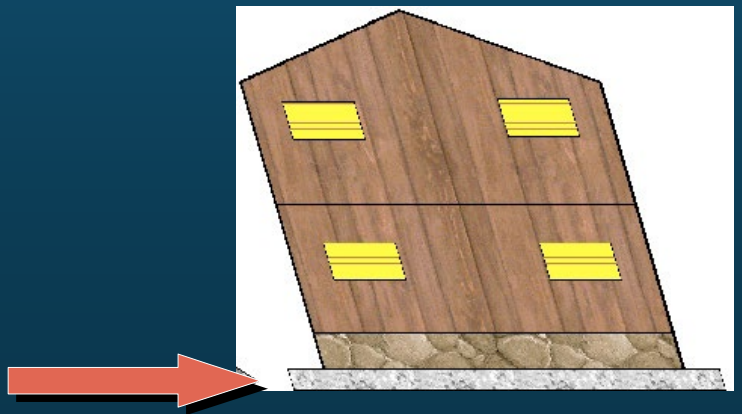
# Period of Vibration



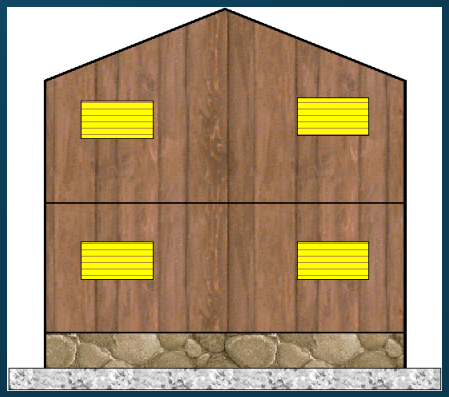
Building at Rest



Ground Accelerates to Left



Ground Accelerates to Right



Ground & Building at Rest

# Chimney Vibration Failure



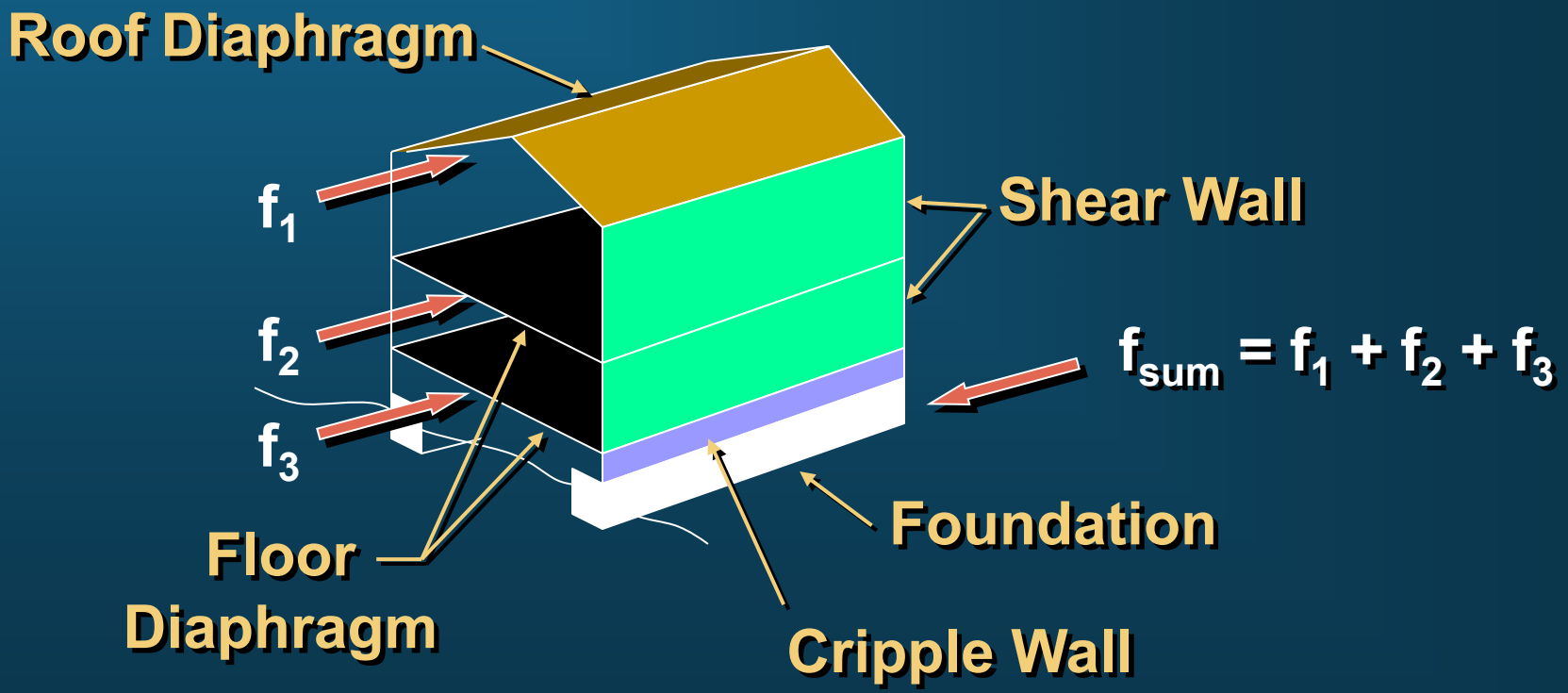
# Porch Vibration Failure



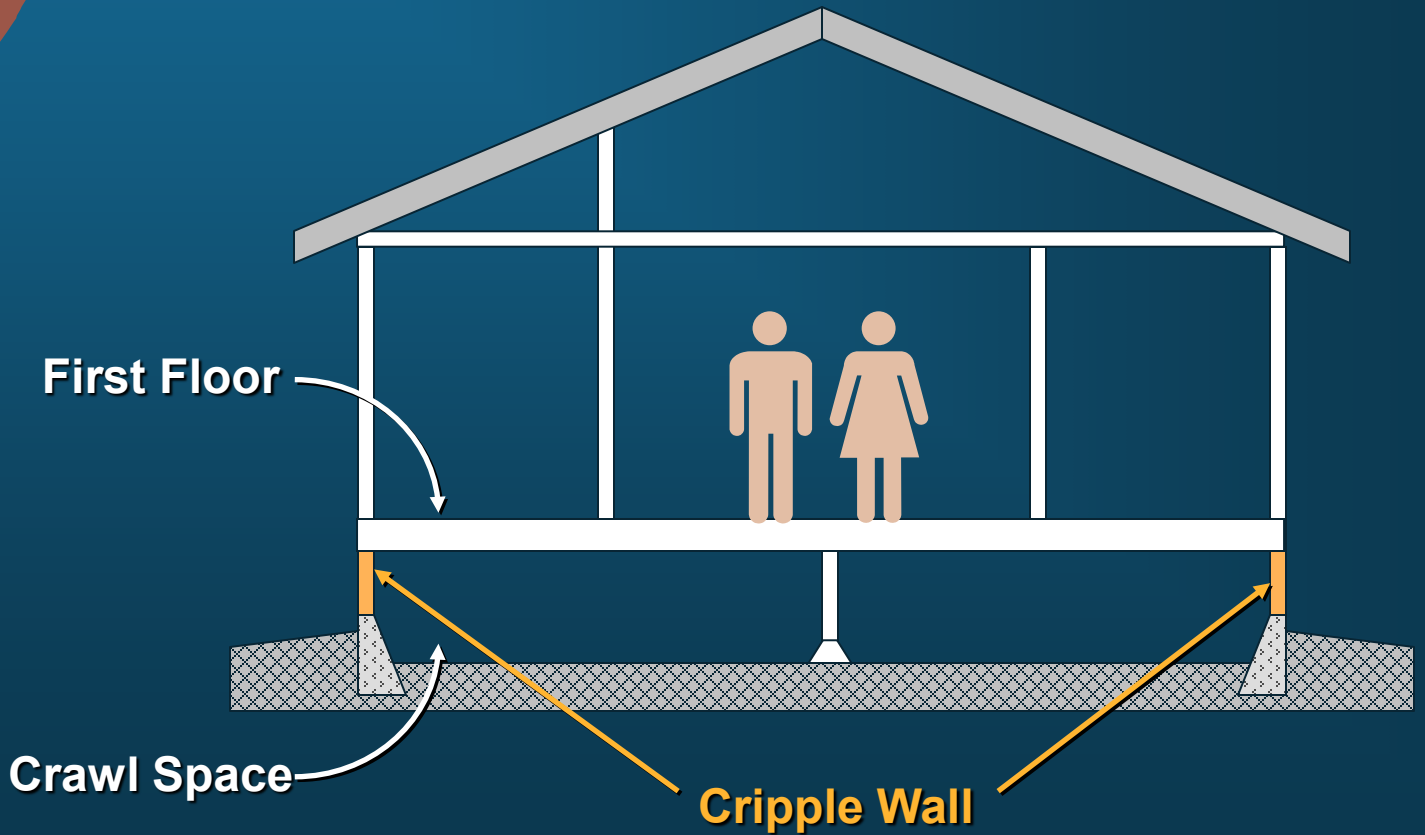
# Two Story Vibration Failure



# House Elements Resist Horizontal Forces



# Cripple Walls



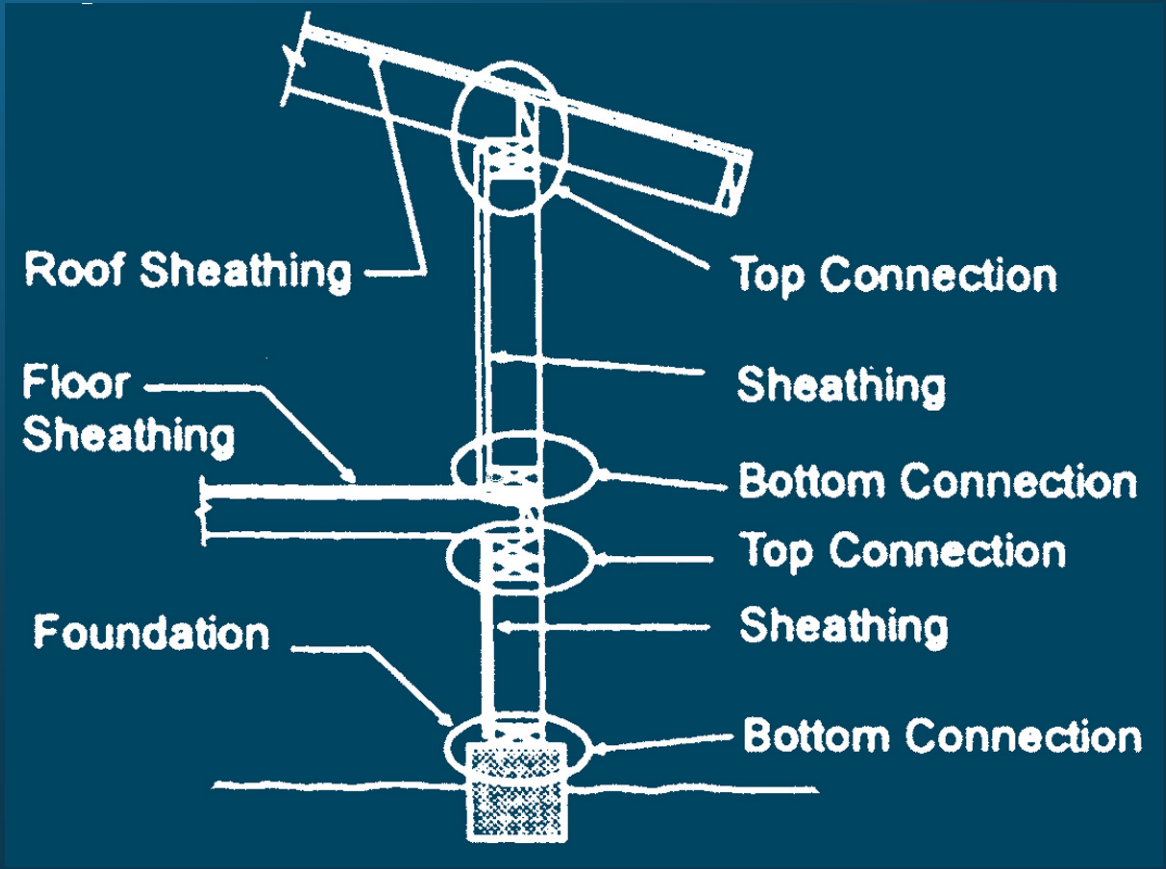
# Damage Resulting from Base Shear

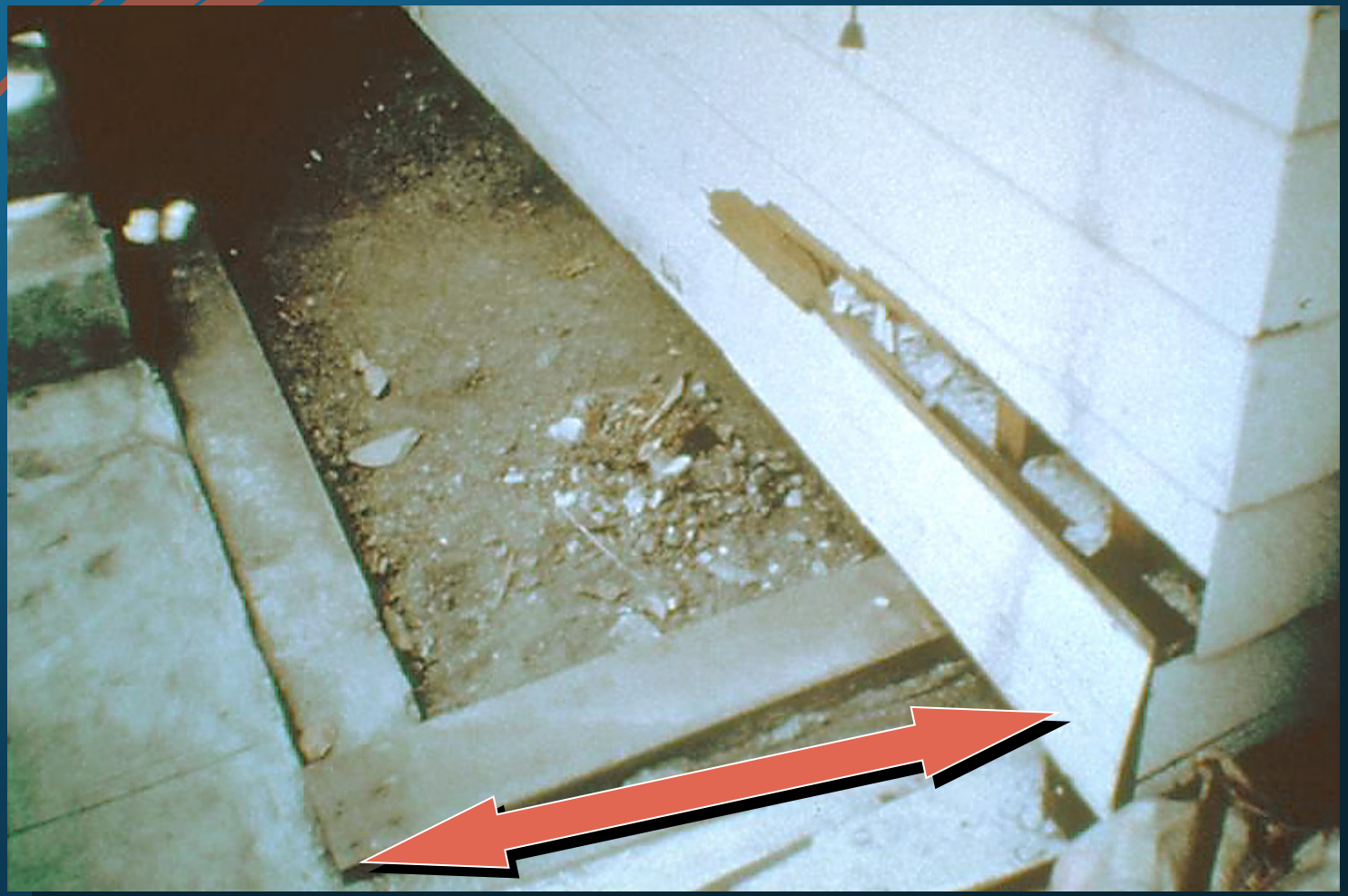


# Buildings Resist Horizontal Earthquake Forces

- **Horizontal parts:**
  - Roof & floor structures ➡ diaphragms
- **Vertical parts:**
  - Span horizontal elements ➡ shear walls

# Complete Load Path



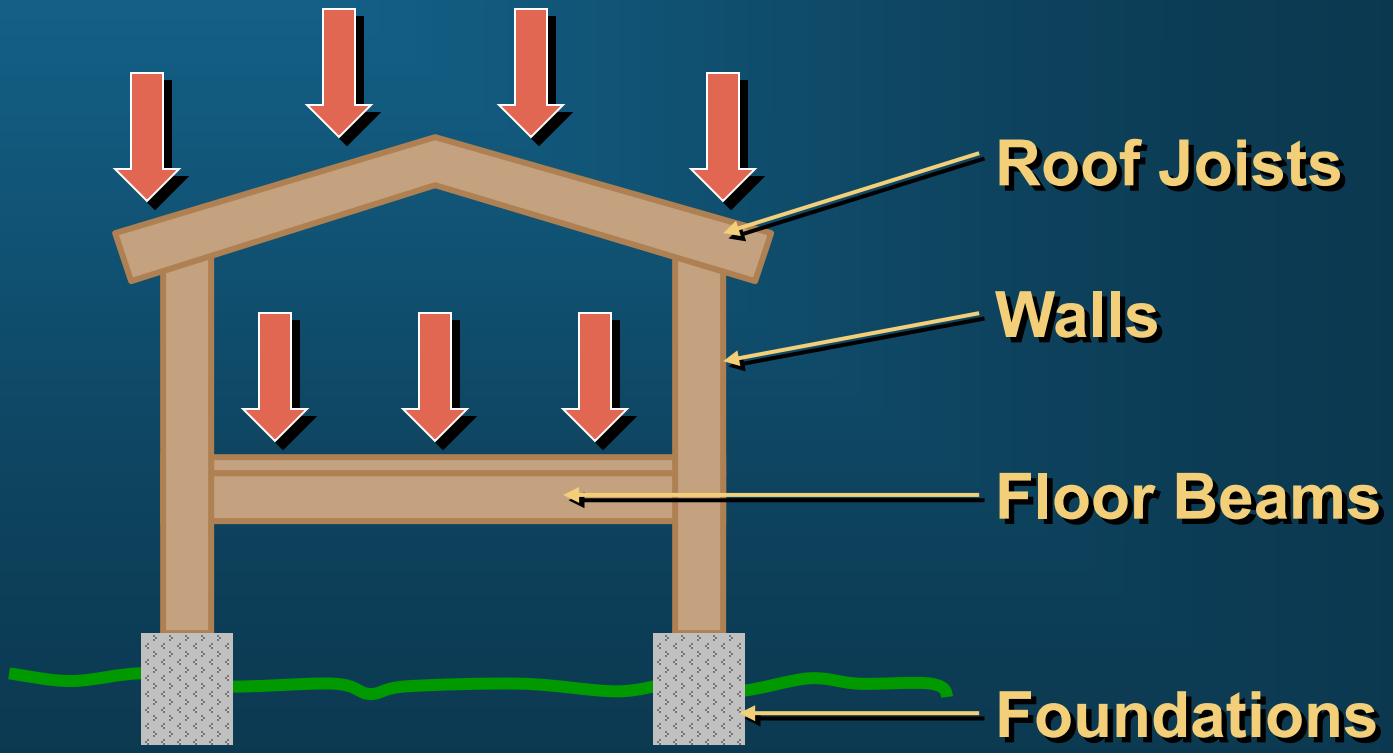


# No Shear Wall at Garage




Steel Moment Frame

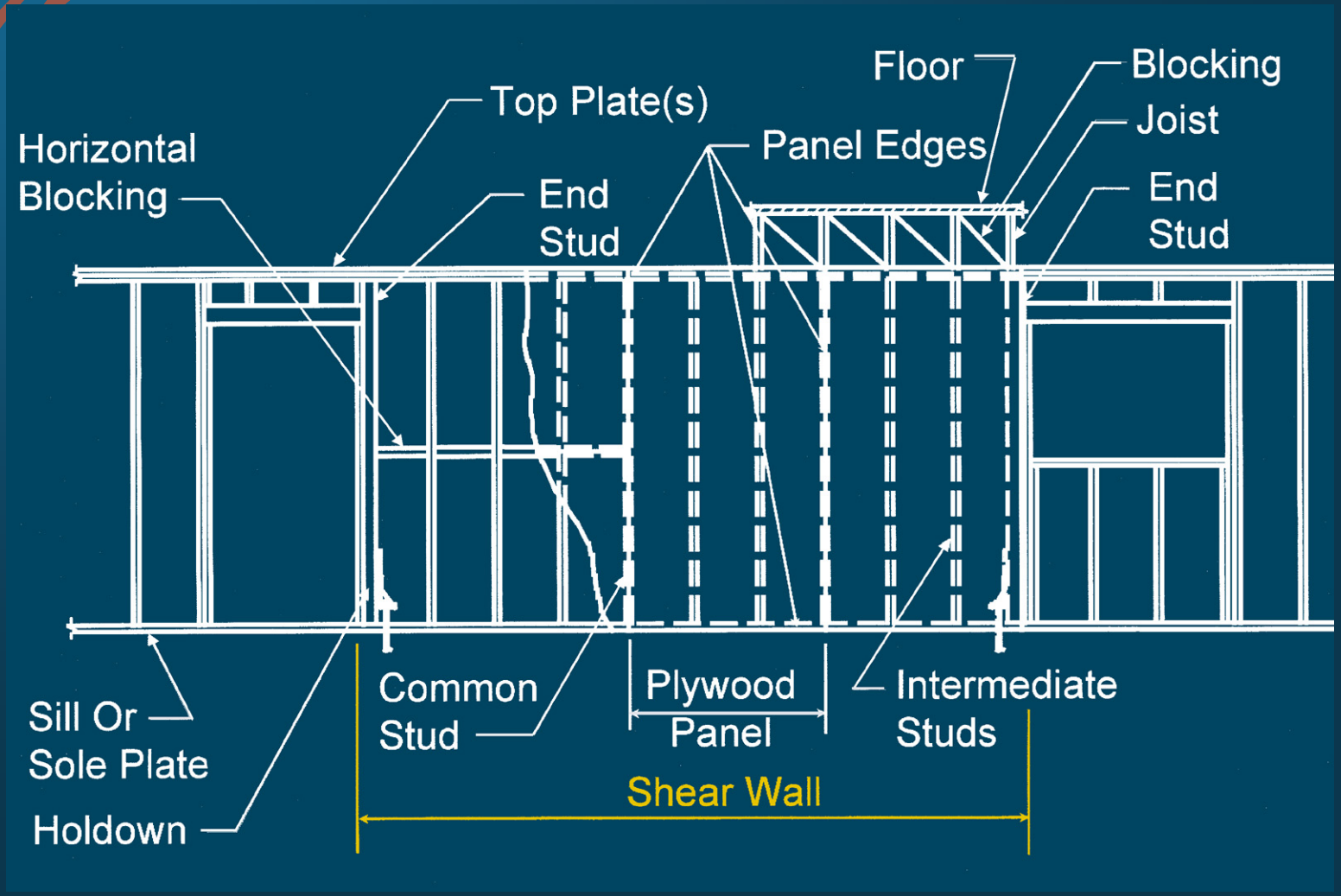
# House Elements Resist Gravity



# Shear Walls

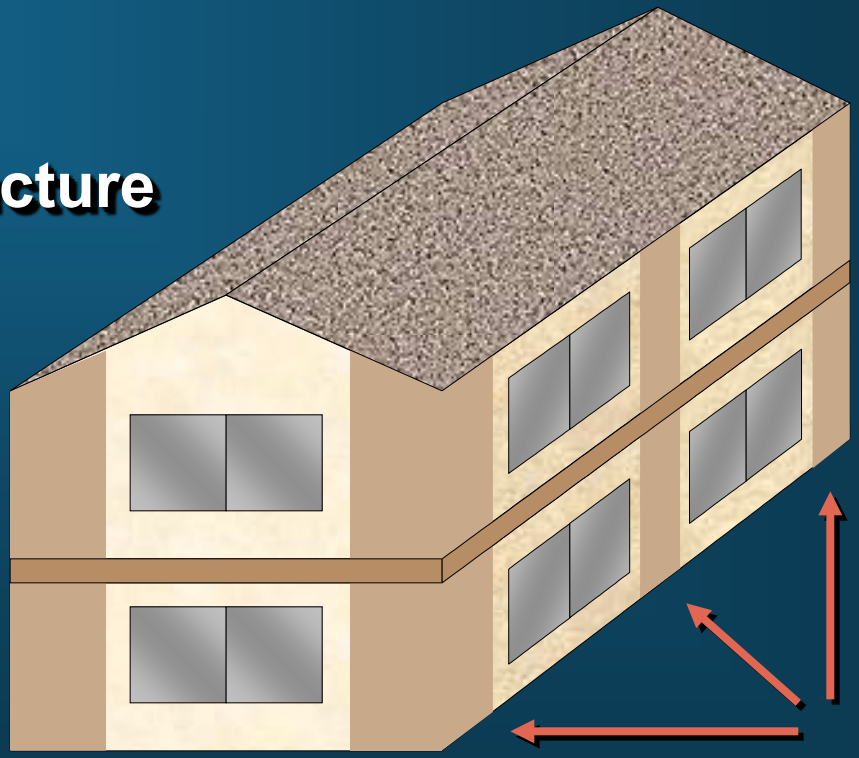
## Section 3

# Typical Shear Wall

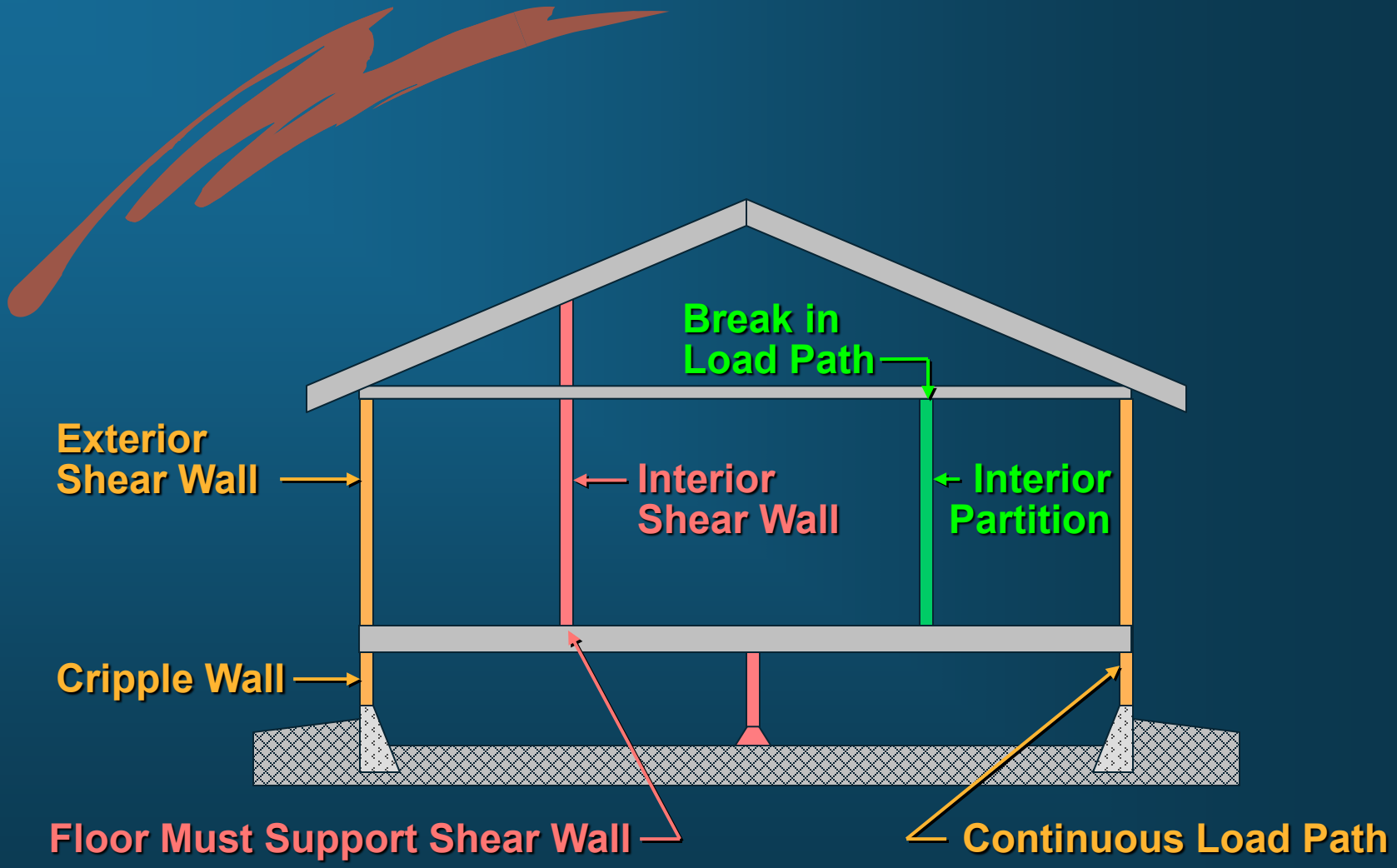


# Location of Shear Walls

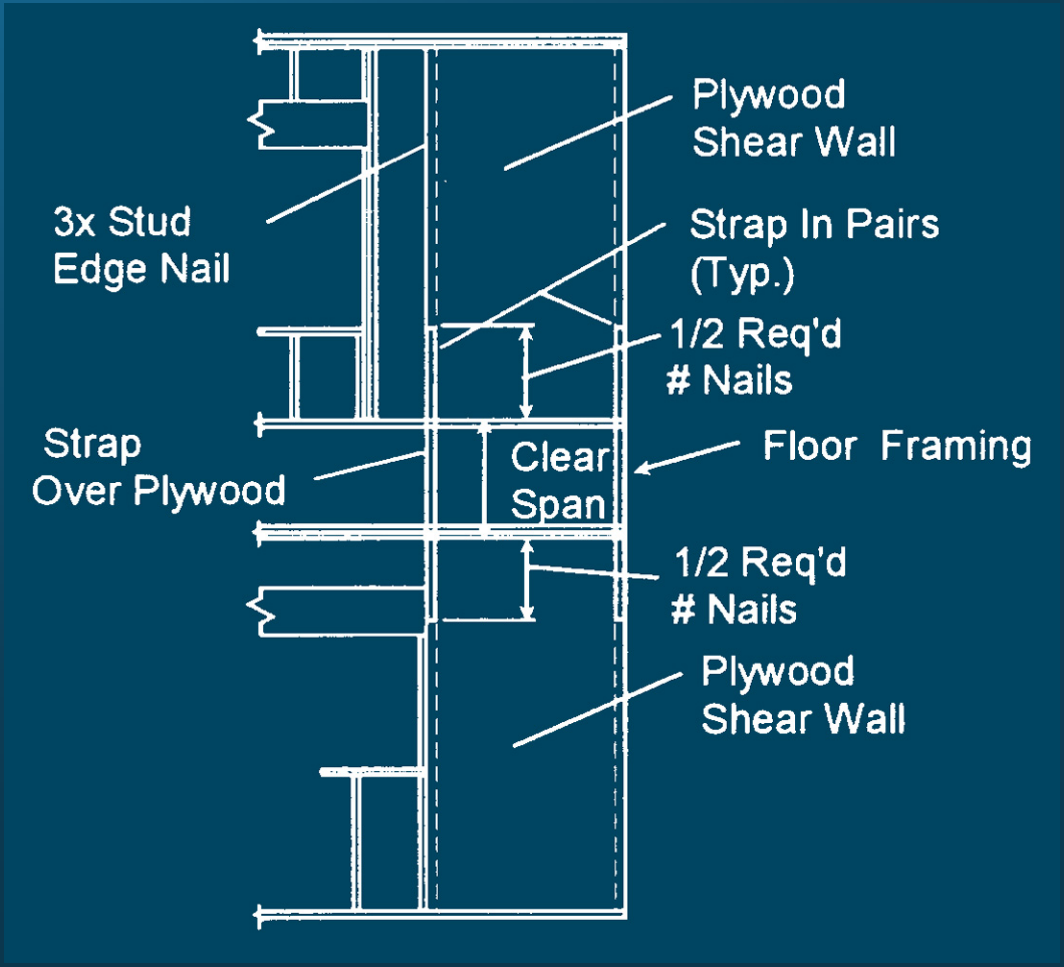
- Create box structure
- Equal length & symmetrical



Even Distribution of Shear Walls


Break in
Load Path
Exterior
Shear Wall
Interior
Shear Wall
Interior
Partition
Cripple Wall
Floor Must Support Shear Wall
Continuous Load Path

# Vertical Offset of Shear Wall



# Shear Wall Over Floor Beam



# Horizontal Shear Forces

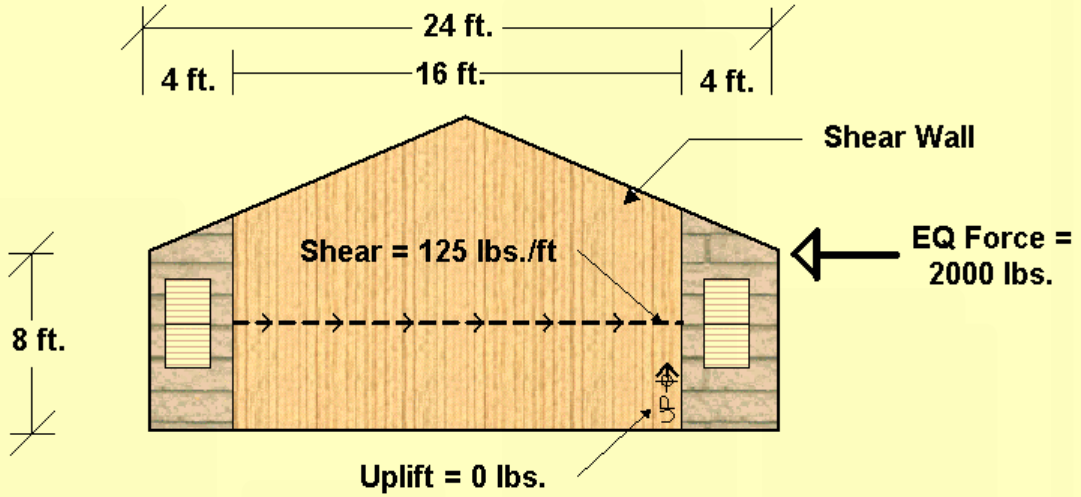


# Uplift Forces On Shear Wall



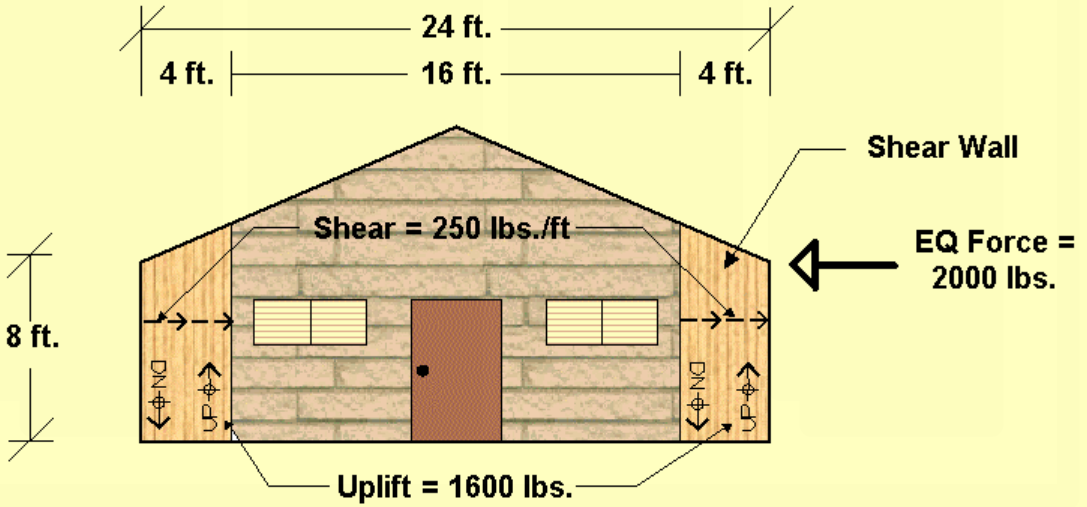
## LOW & LONG WALL

Height-to-Width Ratio: 1/2:1

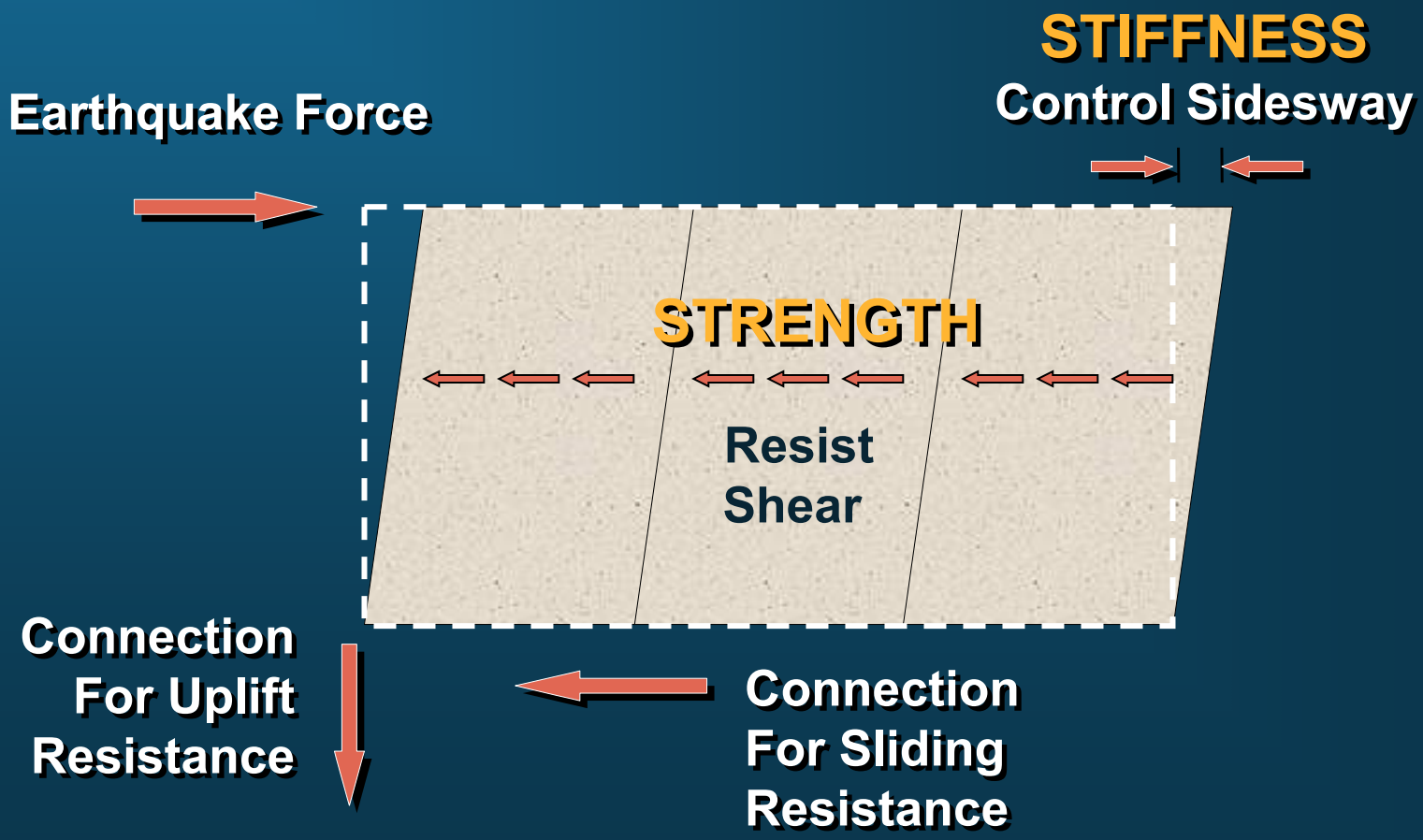



## TALL & SHORT WALL

Height-to-Width Ratio: 2:1



# Two Functions of a Shear Wall



# What Provides Shear Wall Strength?

- Lumber
- Sheathing
- Fasteners

# Lumber Strength Failure



# Sheathing Strength Failure



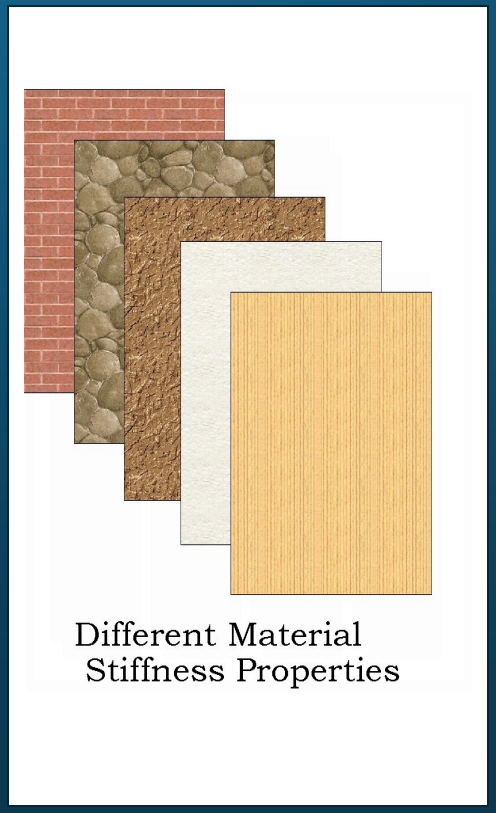
# Fastener Strength Failure

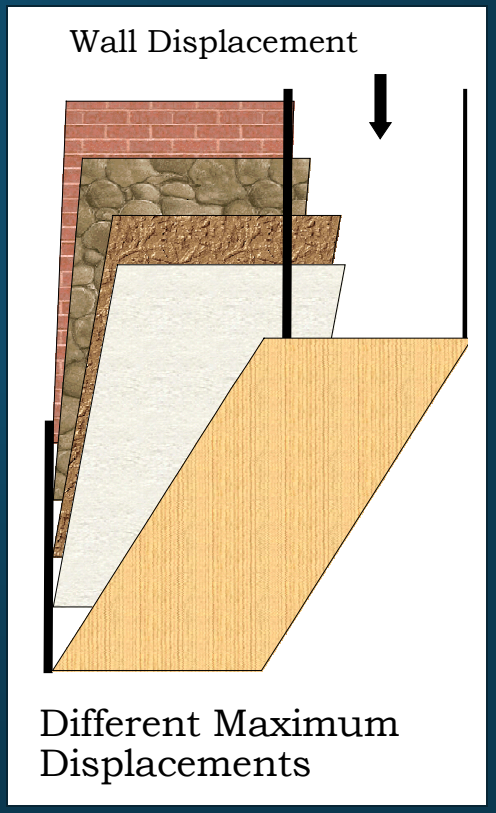


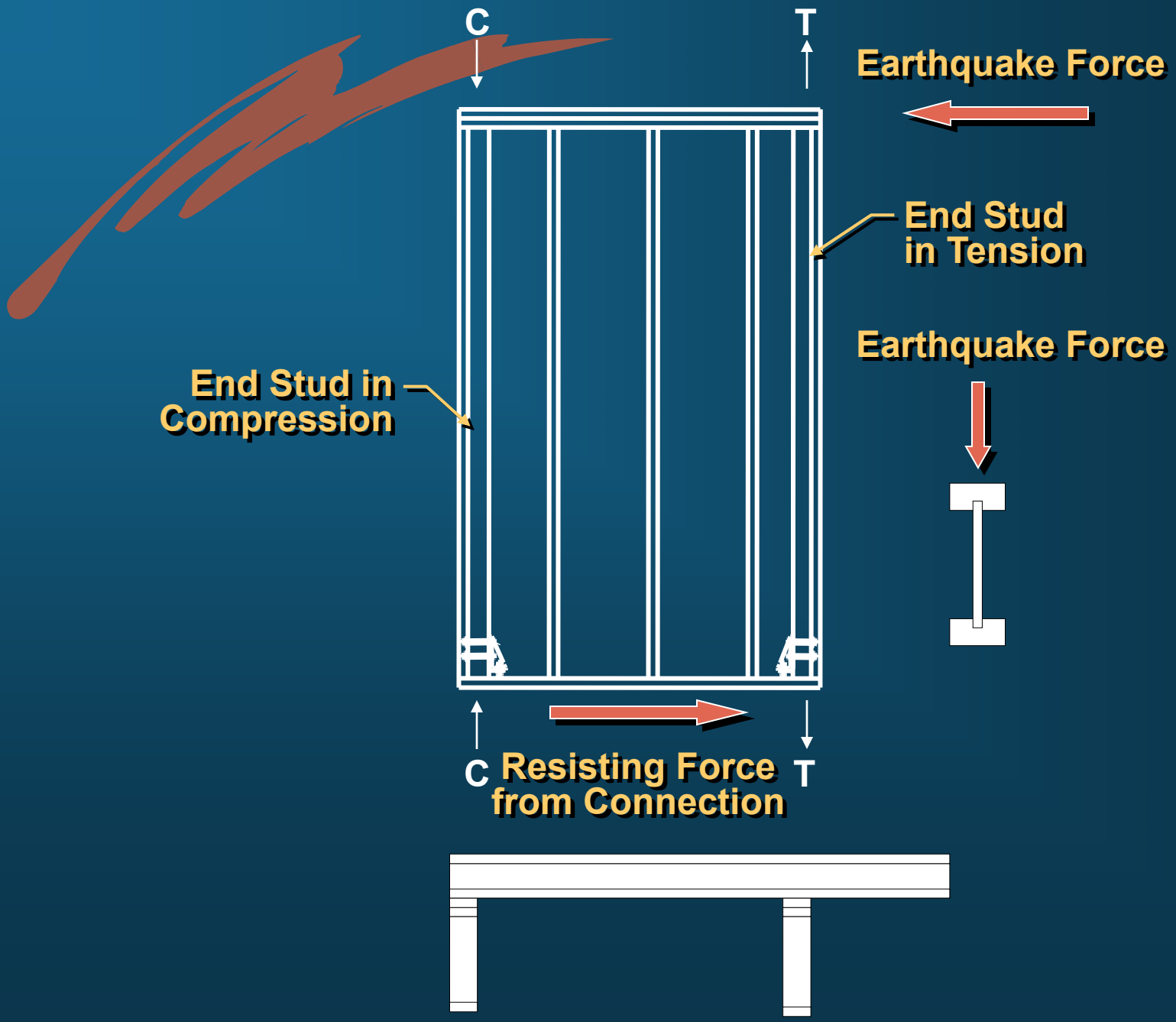
# Combining Different Material Strengths

- Different sheathing materials DO NOT combine strength
- Sheathing materials reach ultimate strength at different wall displacements

# Sheathing Material Strengths




C
T
Earthquake Force
End Stud
in Tension
Earthquake Force
End Stud in
Compression
C
Resisting Force
from Connection
T

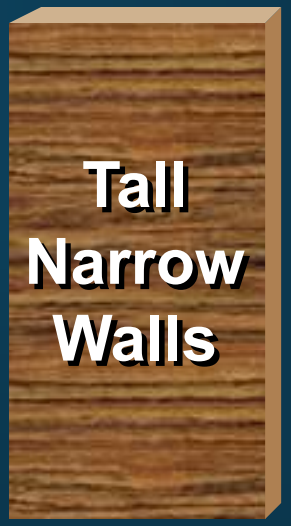
# Most Important Factors

Height

Weight




ARE
STIFFER
THAN



# Allowable Aspect Ratios

| 1994 Uniform Building Code - Wood Frame Shear Values | | | |
|---|---|---|---|
| **Material** | **Allowable Shear, lbs/ft** | **Maximum Height-To-Width Ratio** | **Minimum Width for 8 Foot High Wall** |
| gypsum lath & plaster | 100 | 1½:1 | 5 feet-4 inches |
| gypsum wallboard-unblocked | 100-145 | 1½:1 | 5 feet-4 inches |
| gypsum wallboard-blocked | 125-250 | 2:1 | 4 feet -0 inches |
| Fiberboard | 125-175 | 1½:1 | 5 feet-4 inches |
| portland cement plaster-unblocked | 180 | 1½:1 | 5 feet-4 inches |
| portland cement plaster-blocked | 180 | 2:1 | 4 feet-0 inches |
| diagonal sheathing-conventional | 300 | 2:1 | 4 feet-0 inches |
| diagonal sheathing-special | 600 | 3½:1 | 2 feet-4 inches |
| wood structural panels & particleboard | 140-870 | 3½:1 | 2 feet-4 inches |

# Northridge Earthquake Showed Us:

- Most materials did NOT do as well as predicted
- More material and wider walls needed

# Reduced Code Values

| Shear Wall Sheathing Material | Allowable Shear, lbs./ft | | Maximum Height-To-Width Ratio | |
|---|---|---|---|---|
| | UBC | LABC | UBC | LABC |
| gypsum lath & plaster | 100 | 30 | 1½:1 | 1:1 |
| gypsum wallboard-unblocked | 100-145 | 30 | 1½:1 | 1:1 |
| gypsum wallboard-blocked | 125-250 | 30 | 2:1 | 1:1 |
| fiberboard | 125-175 | 0 | 1½:1 | - |
| portland cement plaster-unblocked | 180 | 90 | 1½:1 | 1:1 |
| portland cement plaster-blocked | 180 | 90 | 2:1 | 1:1 |
| plywood -3 ply panels | 200-770 | 150-200 | 3½:1 | 2:1 |
| plywood & OSB- 3/8 inch | 200-730 | 150-200 | 3½:1 | 2:1 |
| particleboard | 140-870 | 175 | 3½:1 | 2:1 |
| diagonal sheathing-conventional | 300 | 300 | 2:1 | 2:1 |
| diagonal sheathing-special | 600 | 600 | 3½:1 | 2:1 |
| wood structural panels | 200-870 | 150-650 | 3½:1 | 2:1 |

# Drywall Failure



# Stucco Failure



# Narrow Panel Failure



# Successful Plywood Coverage



# Wood Structural Panel Shear Walls

- Lumber type
- Lumber size
- Condition of existing wood

# Stronger




Douglas Fir-Larch

# Weaker




Hem Fir

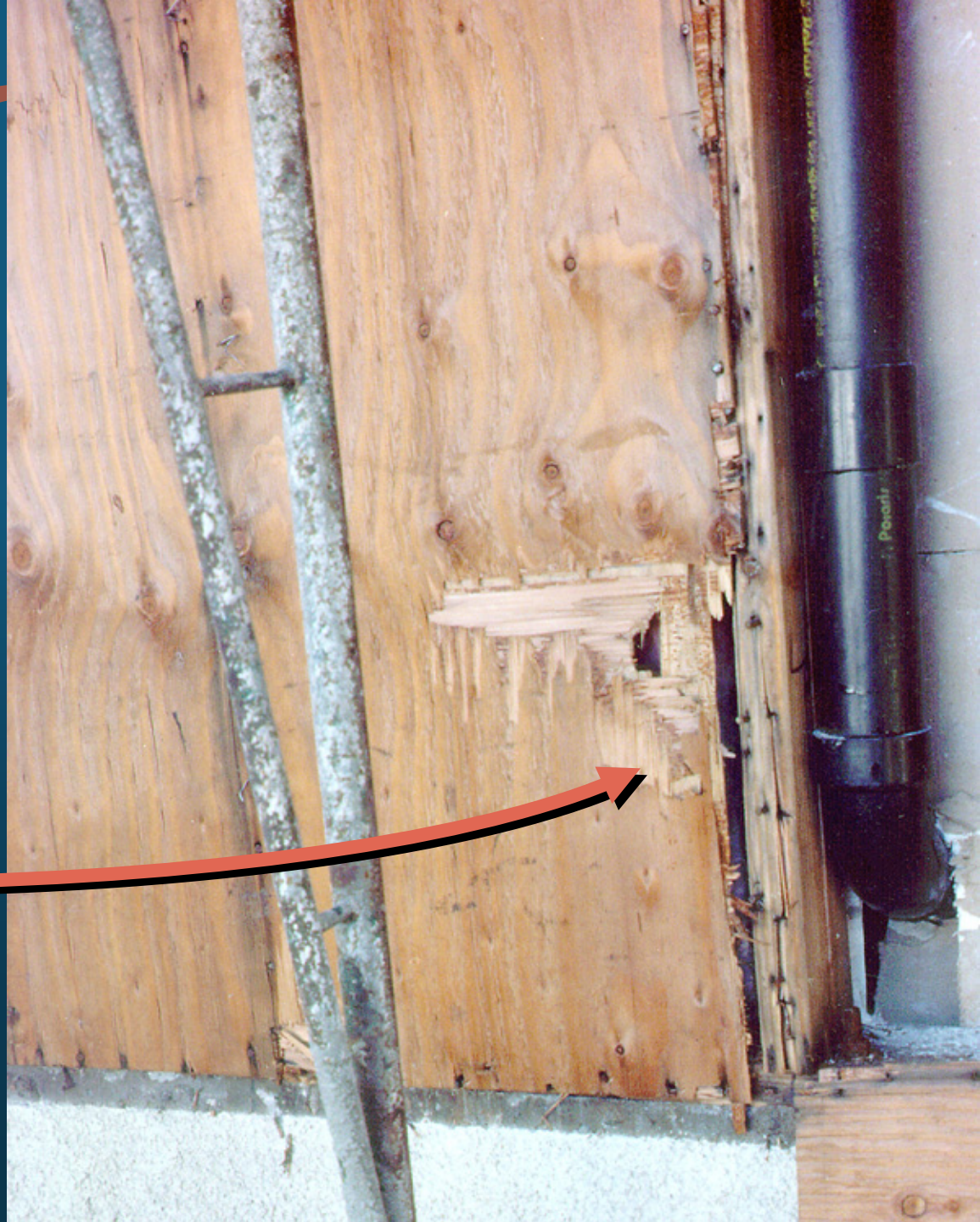
# Effect Of Lumber Species On Stren

| Wood Structural Panel | | Common Nail Sizes | Nail Spacing at Panel Edges | Allowable Shears (lbs/ft) Based on Lumber Species | | |
|---|---|---|---|---|---|---|
| Panel Grade | Thickness | | | Douglas Fir-Larch | Hem-Fir | Redwood Open Grain |
| Structural 1 | 15/32 in | 8d | 4 | 430 | 355 | 280 |
| Structural 1 | 15/32 in | 8d | 3 | 550 | 450 | 360 |
| Structural 1 | 15/32 in | 10d | 3 | 665 | 545 | 430 |

# Use Proper Size Stud

- Framing members split at ultimate loads when sheathing nails are closely spaced
- Shear Walls: 17% stronger when 3” framing used throughout

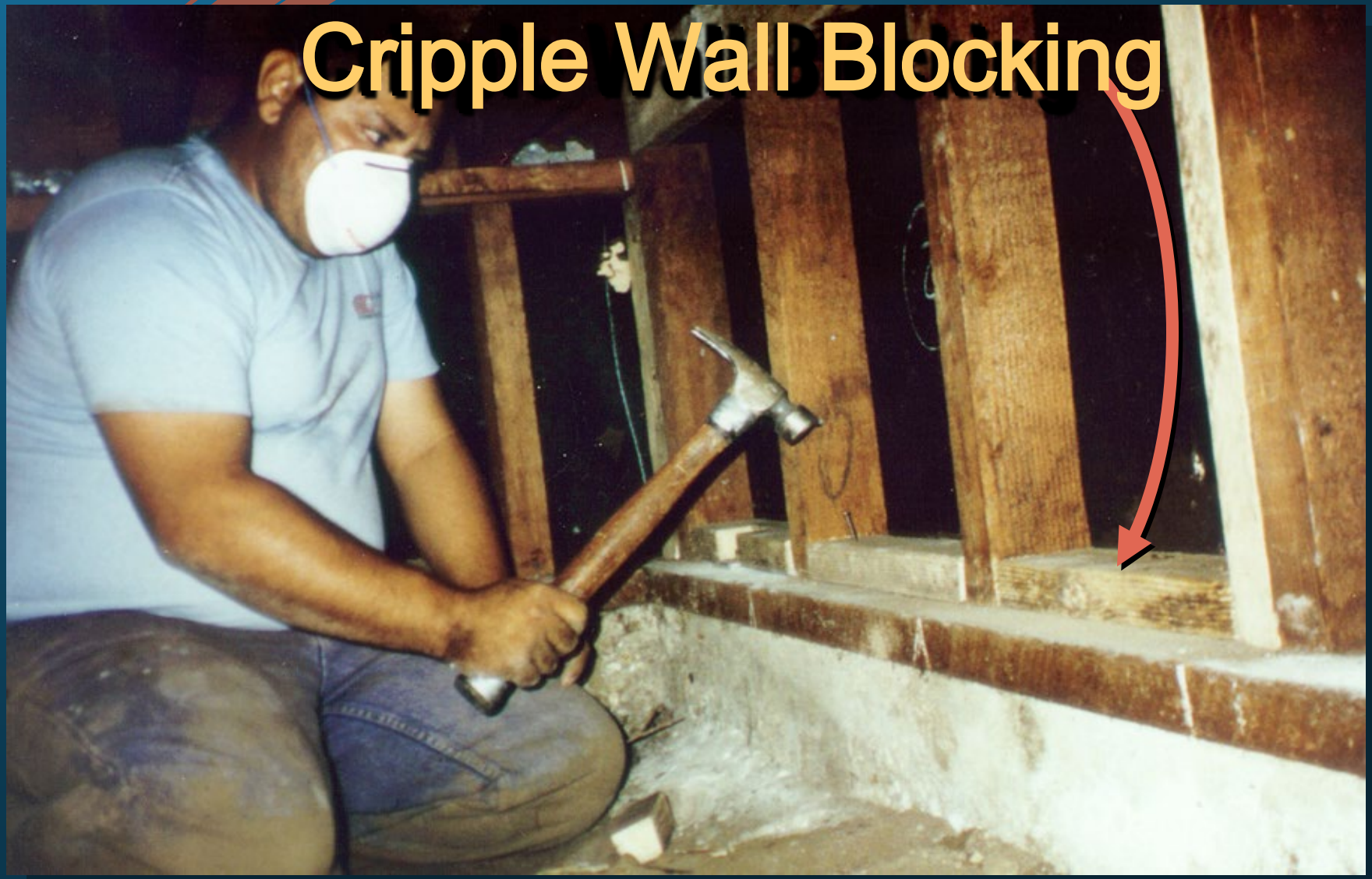
2”
Adjoining
Stud



# Install Proper Size Blocking

- Fasten all edges to framing members or blocking
- Provide blocking if panel members are unsupported between framing members

# Cripple Wall Blocking



# 3” Flat Blocking



# Reinforced Window Opening in Shear Wall



# Blocking For Opening Reinforcement



# How is the Length of Shear Wall Measured?

- Horizontally along sheathing between wall ends with hold-downs
- NOT length of plywood
- IS measured by hold-down location

# What's Wrong?

Too close to end wall; countersunk

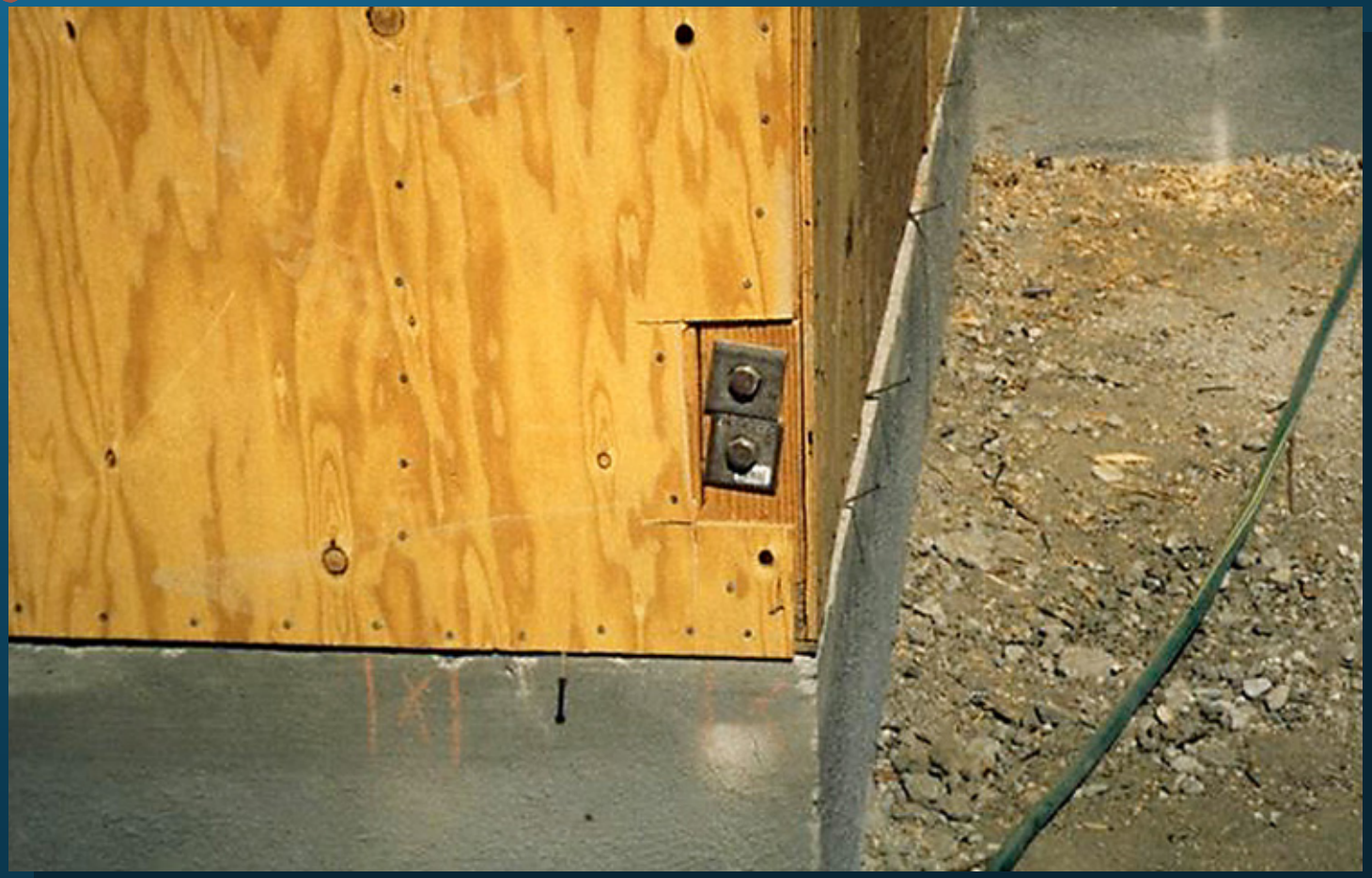


# What's Wrong?

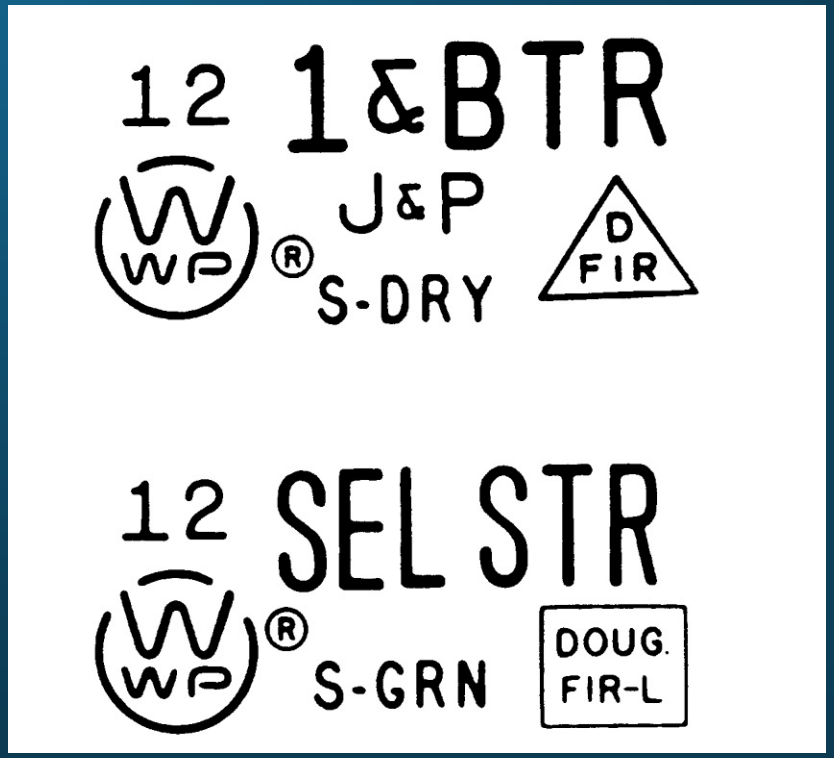
Too far from shear wall end



# Acceptable Hold Down Location



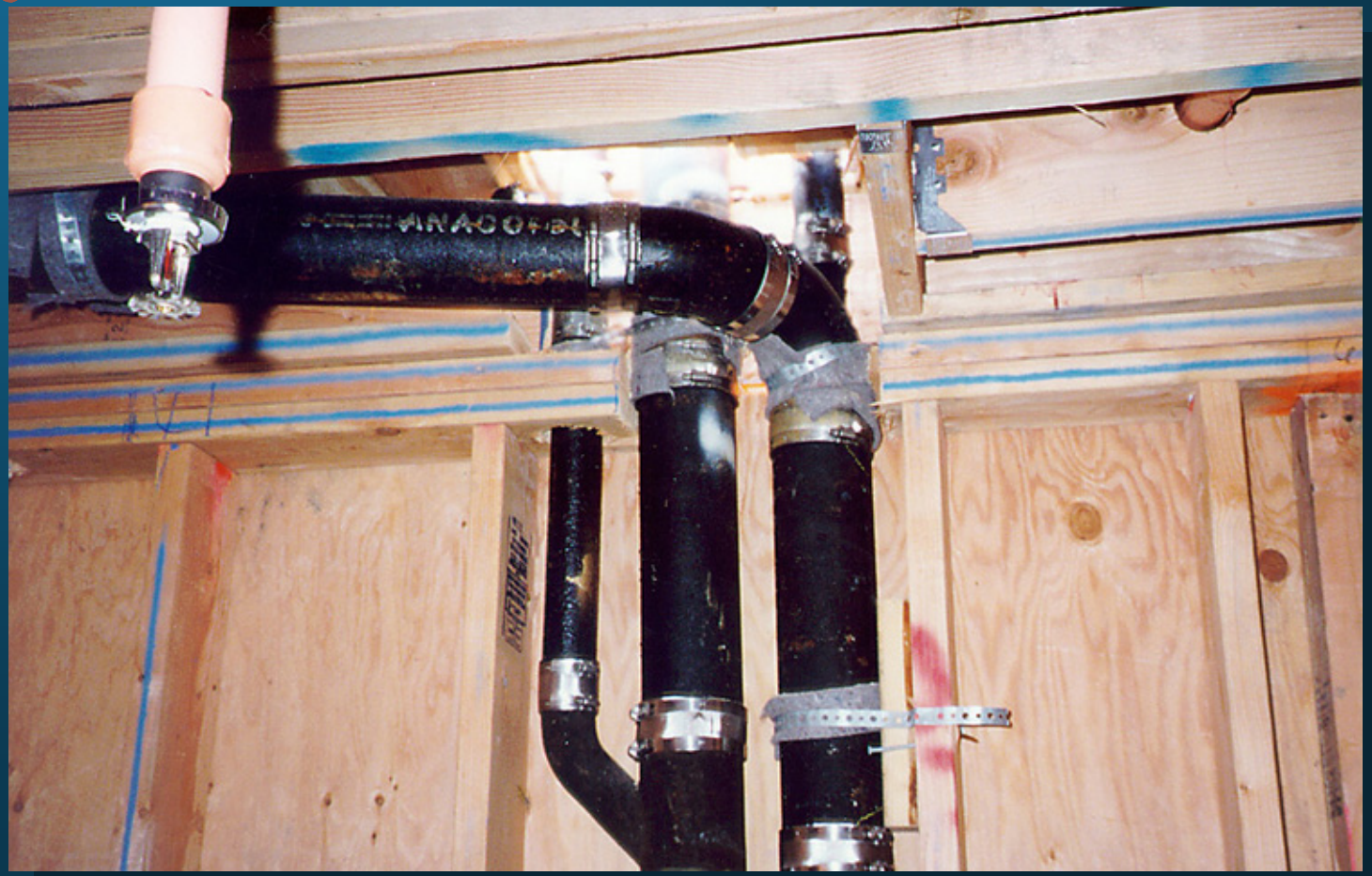
# Lumber Grade

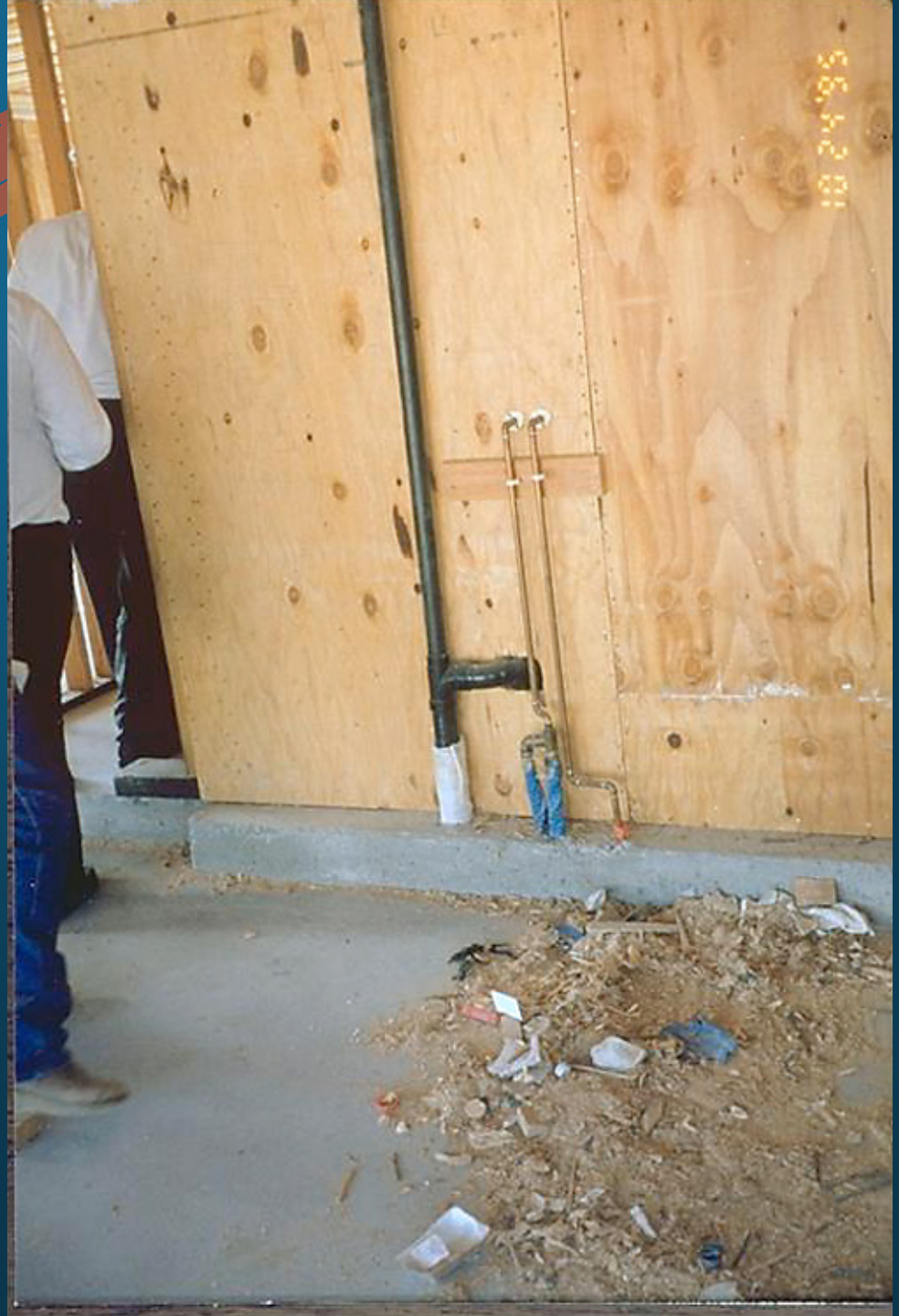


# Effect of Lumber Grade on Hold-Down Capacity

| Holdown Product | Stud Size | Douglas Fir-Larch Grade | Catalog Value | Tension, lbs | Compression, lbs | | |
|---|---|---|---|---|---|---|---|
| | | | | Net Section | 8 Ft. Stud | Sill or Sole Plate | |
| | | | | | | Hem fir | DF-L |
| HD 8A | 4 x 4 | No. 1 | 7,460 | 12,078 | 7,695 | 4,961 | 7,656 |
| | | No. 2 | | 10,288 | 7,209 | | |
| | | Construction | | 7,753 | 6,840 | | |
| | | Standard | | 4,473 | 6,327 | | |
| | | Stud | | 5,905 | 5,965 | | |

# Penetration Through Shear Wall







# Wood Decay



# Termite Damage



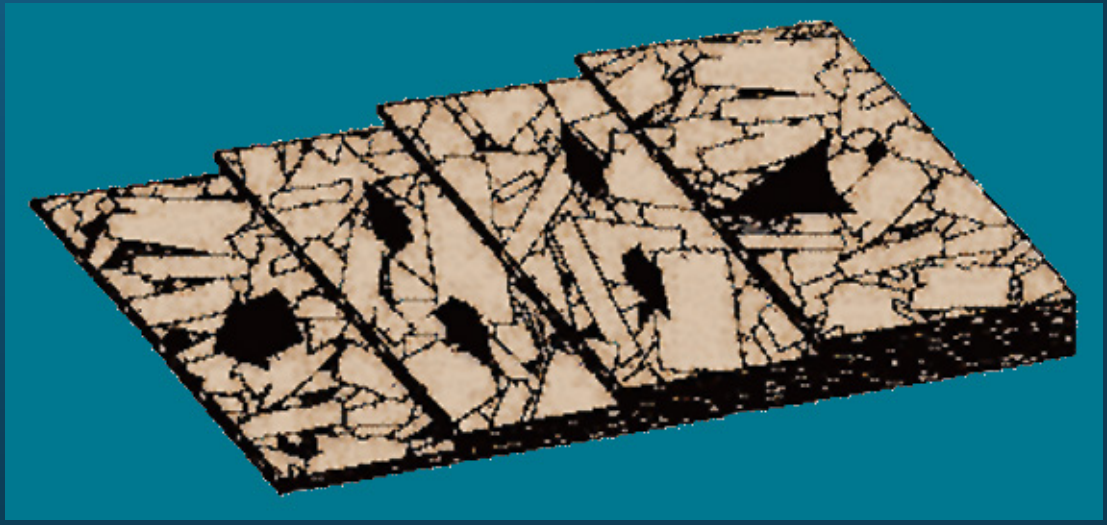
# Crawl Space Ventilation



# Installing the Sheathing

- Use specified wood structural panel
- OSB
- Plywood

# Construction of Oriented Strand Board Panel

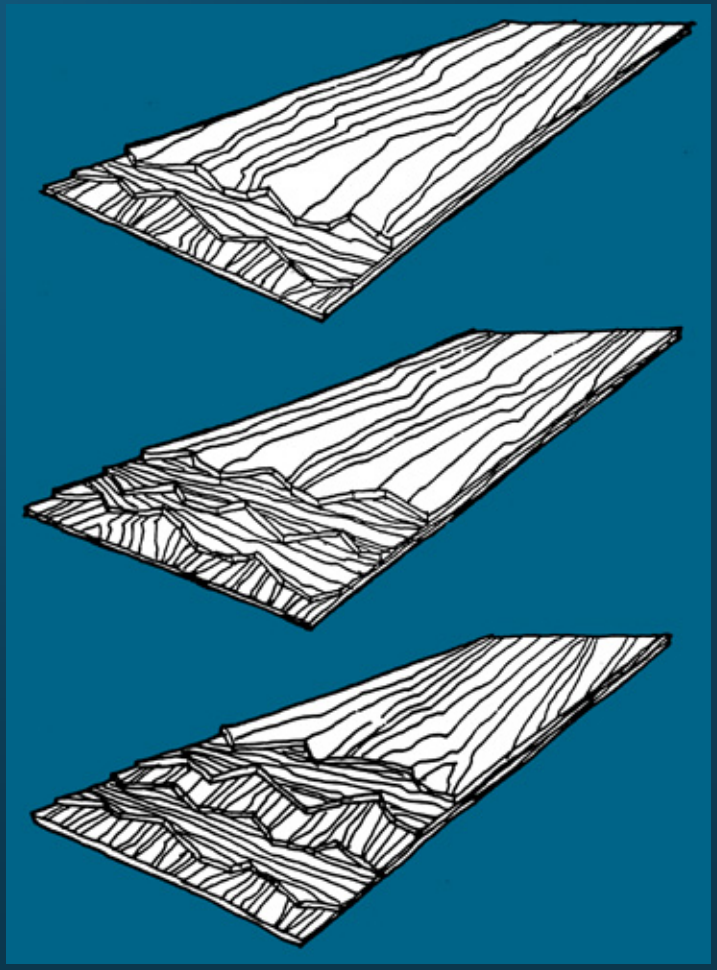


# Construction of Plywood

3 ply
3 layer panel

4 ply
3 layer panel

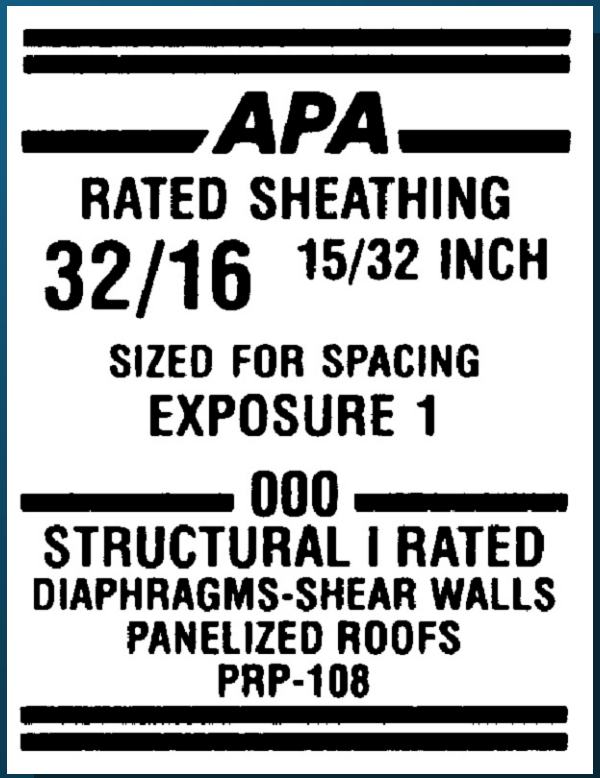
5 ply
5 layer panel



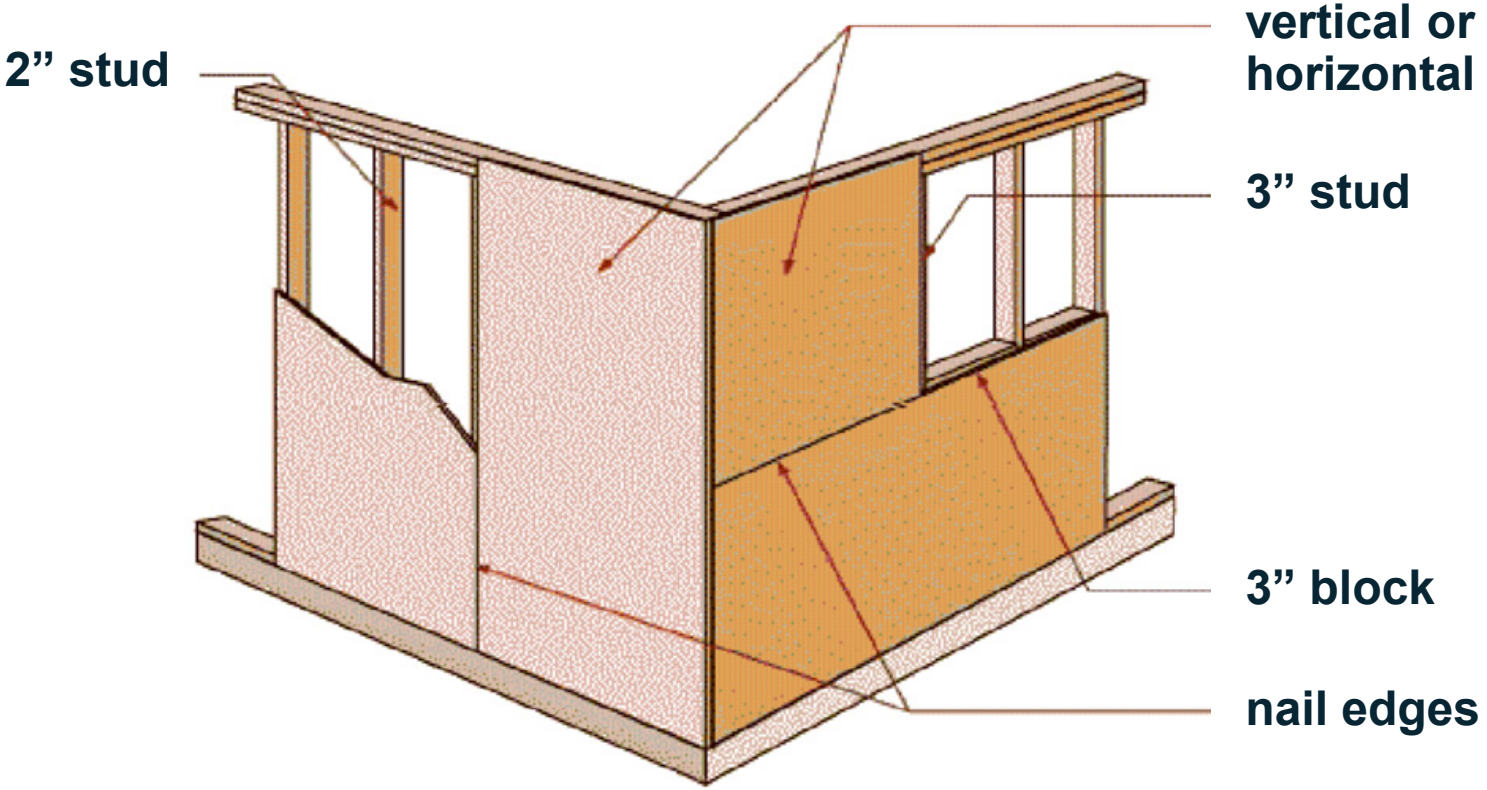
# Minimum Recommended Thickness

- 15/32”
- Both 4ply and 5ply
- More plies ⇨ stronger sheathing

# Use Correct Panel Grade



# Sheathing Orientation



- **Use proper size panel**
  - 2:1 aspect ratio
  - 4’ x 8’ panel minimum
- **Mark stud locations on panels**
  - Avoid improper fastening
- **Maintain fire resistive and sound rated construction**
  - Don’t change anything!

# Cripple Wall Ventilation



# Shear Wall Fasteners

# Use Common Nails



MADE FOR USE IN:

| MANUFACTURER | MODEL NO. |
|---|---|
| HITACHI | NR-83A |
| MAKITA | AN-8300 |
| STAN-TECH | SDN11,SDN11B |
| ATRO | RHS921 |
| PASLODE | 5350/SRH-20 |
| SENCO | SN60,SN65 |

"ENGINEERED CONSTRUCTION NAILS" THAT MEET OR EXCEEDS THE REQUIREMENTS OF ASTM F 1667

REF: HSD .148 3.000 – 4M

IWP - AD ICBO# 2843

GOLDEN STATE NAIL CO.

GSN ITEM: HS10D148 – 4M

3 X .148
SMOOTH
(10D COMMON)

ROUND HEAD STRIP NAILS

4000 NAILS PER BOX

HS10D148-4M

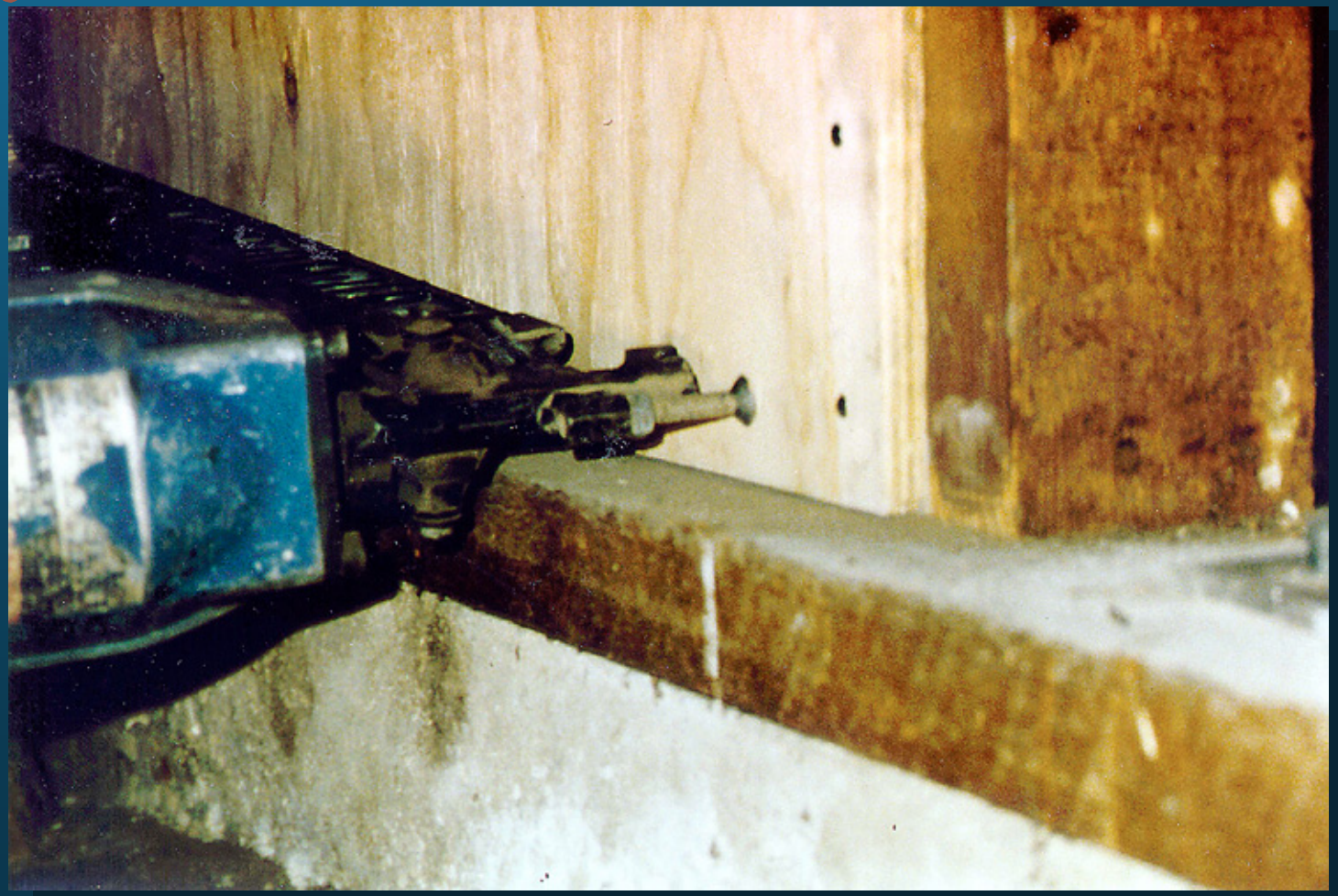
MADE IN U.S.A.

# Use Proper Nail Length and Head Size

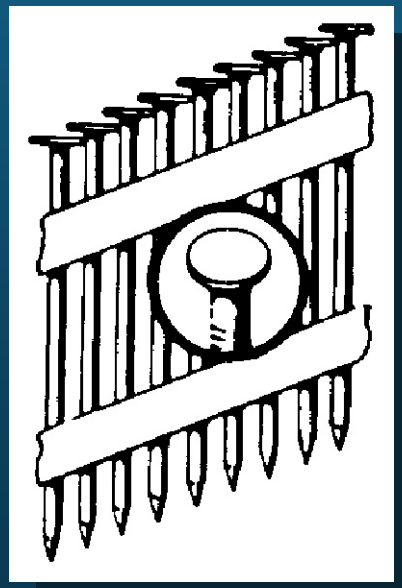
# Performance Losses for Nail Substitutions

| COMPARISON OF COMMON VS. BOX NAILS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nail Size | Length, inches | Shank Diameter, decimal inch | | Minimum Spacing and Penetration, inches | | Allowable Lateral Load, pounds | | |
| | | Common Nail | Box Nail | Common Nail | Box Nail | Common Nail | Box Nail | Box vs. Common |
| **6d** | 2 | 0.113 | 0.099 | 1¼ | 1⅛ | 63 | 51 | **0.81** |
| **8d** | 2½ | 0.131 | 0.113 | 1½ | 1¼ | 78 | 63 | **0.81** |
| **10d** | 3 | 0.148 | 0.128 | 1⅝ | 1½ | 94 | 76 | **0.81** |

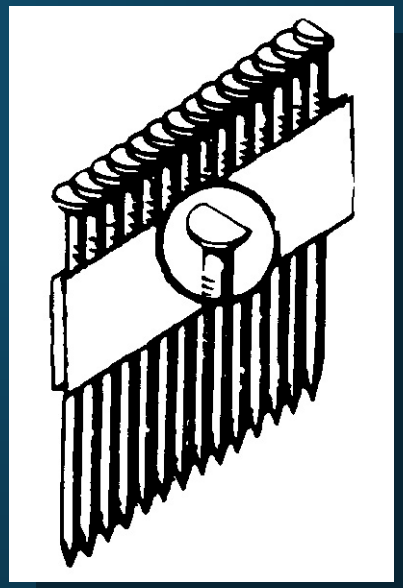
# Nail Gun With Flush Attachment



## Round Head Nails (P-Nails)



## Modified Round Head Nails (P Nails)



# Clipped Nail Head

Smaller nail head areas → smaller shear wall strengths



## 1994 UBC:

Nail should “not fracture the surface of the sheathing”

## 1997 UBC:

The “head or crown of the nail is flush with the surface of the sheathing”

***Overdriven nails reduce shear wall strength***

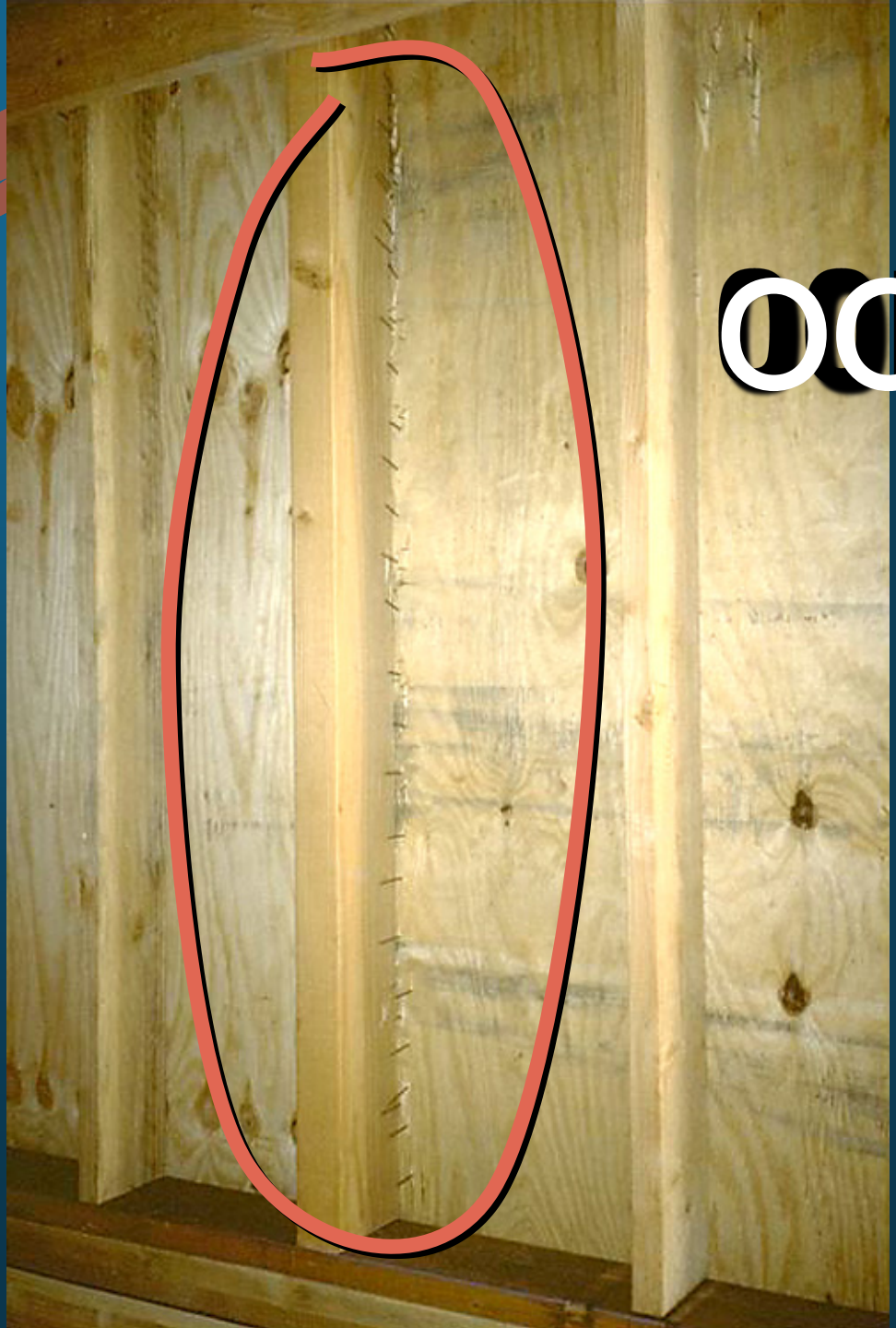
Overdriven Nails



Improper Edge Distance

# Important

- Install nails flush to sheathing
- Maintain proper sheathing edge distan
- Check for splitting
- Remove improperly installed nails
- Provide proper edge nailing



# OOPS!

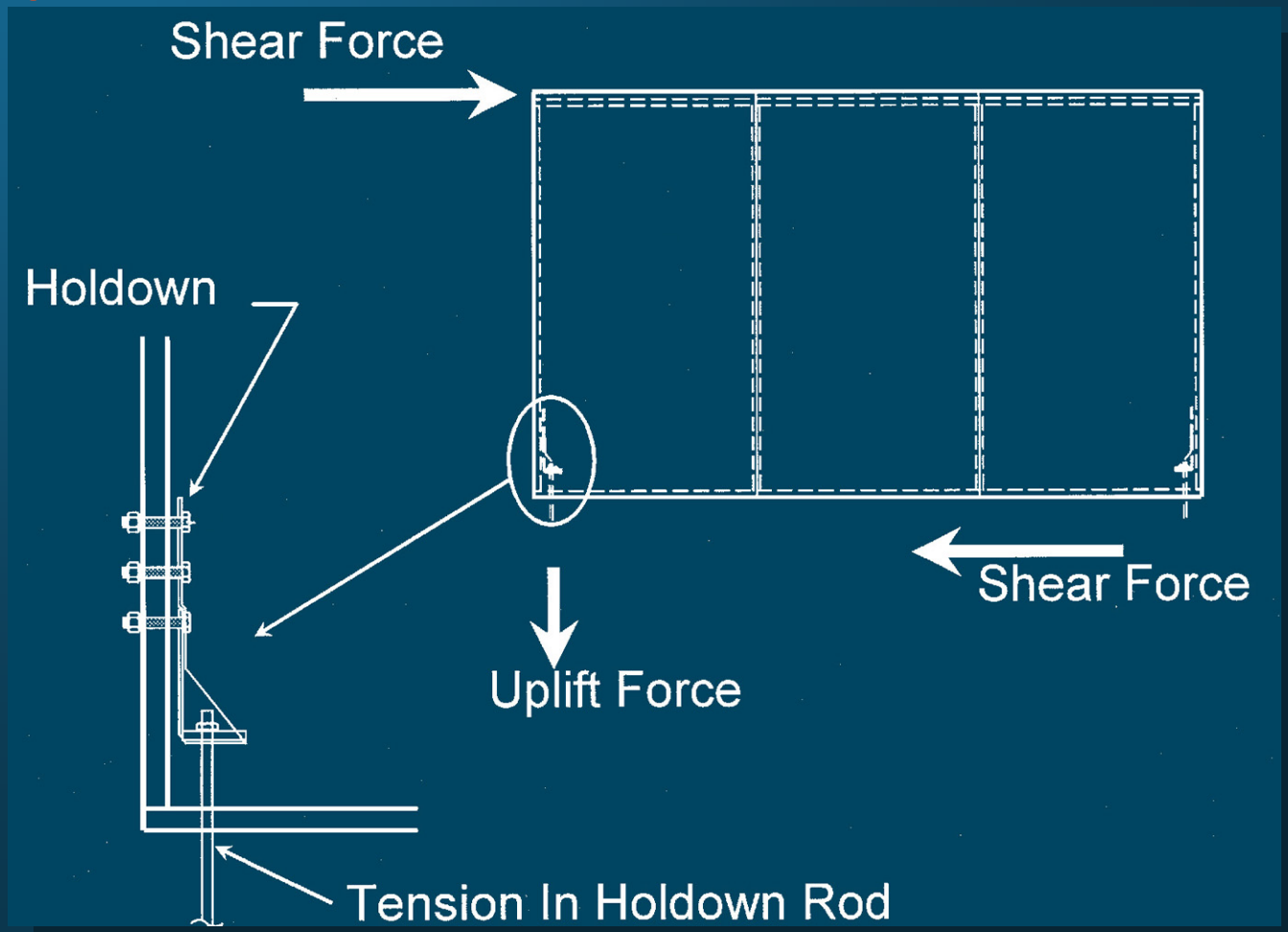
# How to Nail a Shear Wall

- **Edge nail**
  - hold-down stud(s)
  - upper top plate
  - sill or sole plate
  - blocking for individual panel edges
  - blocking for opening reinforcement
- **Field nail** the studs between the panel edges

# Connections

Section 4

# Uplift Force in Hold Down



# Hold-Downs

- No prescriptive requirements
- Architect / engineer specifies installation
- Typically required both ends of shear wall connected to end stud or post

# Hold-Downs Connect Walls Through the Floor





# Proper Installation



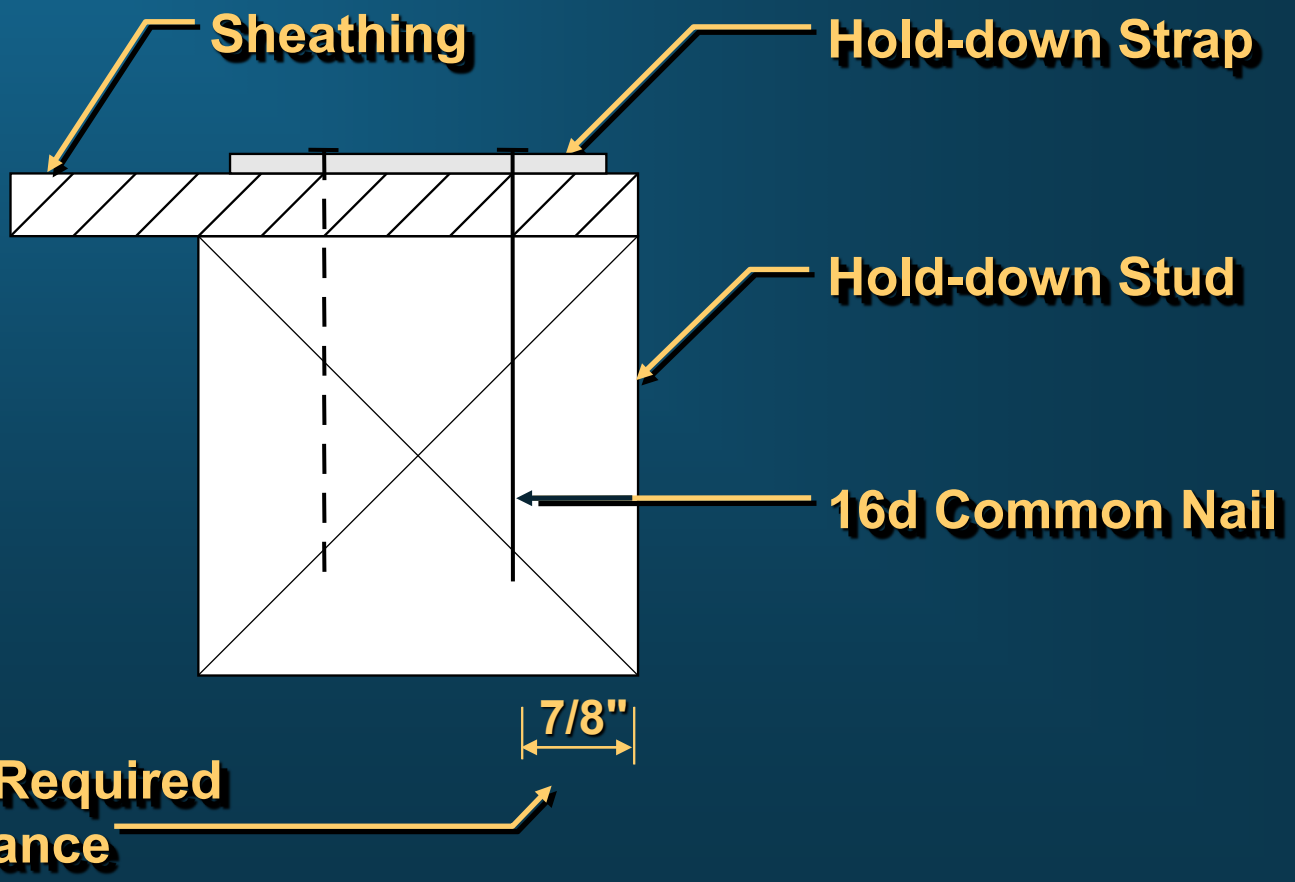
# Common Errors

- ☹ Failure to follow manufacturer's installation instructions
- ☹ Hardware substitutions

# Double Stud Reduces Strength



# Maintain Minimum Edge Distance





# Improper End Distance



# Oversize Bolt Hole



# Undersized Washers



# Countersunk Nut and Washer

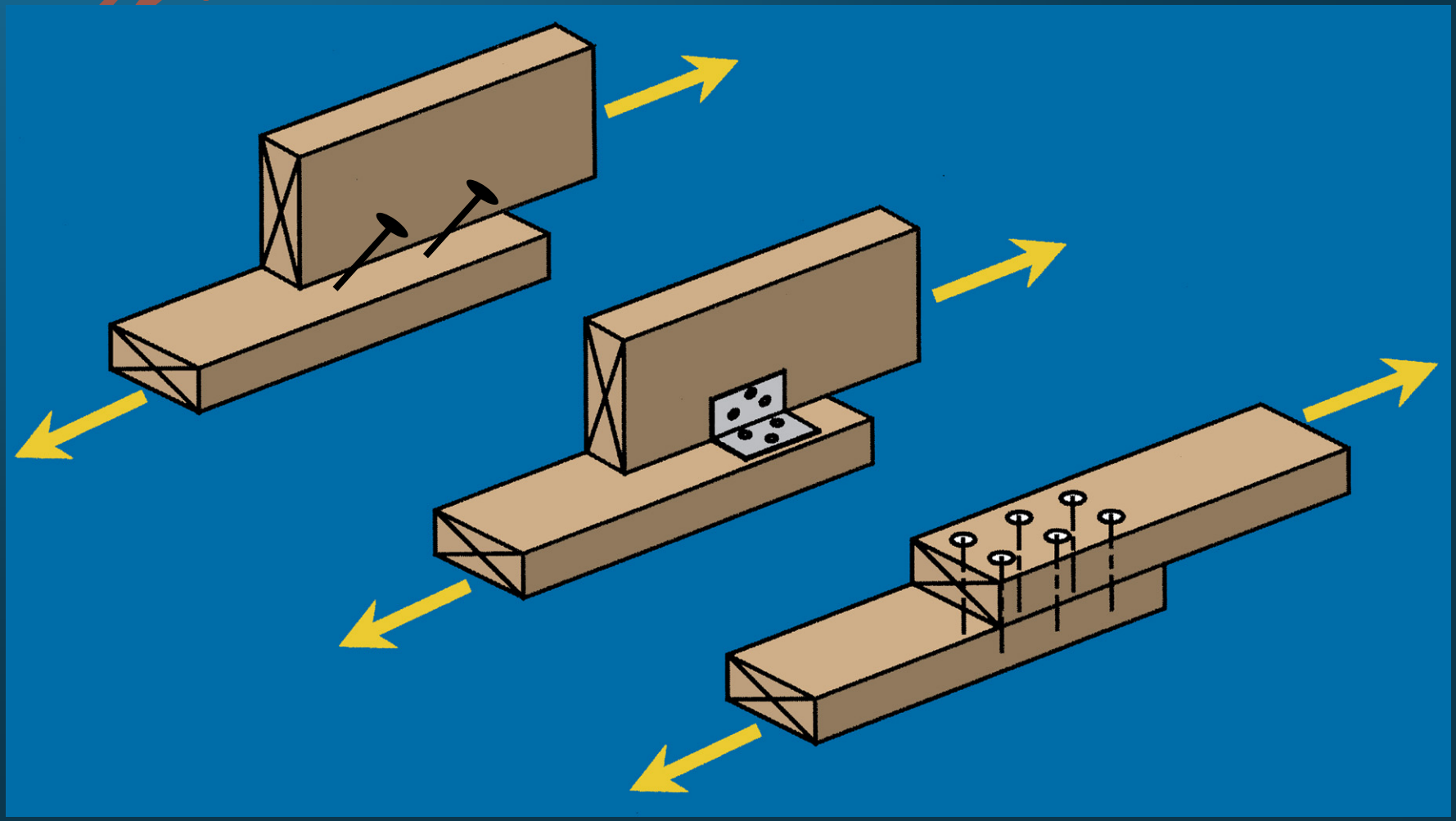



Insufficient
Embedment

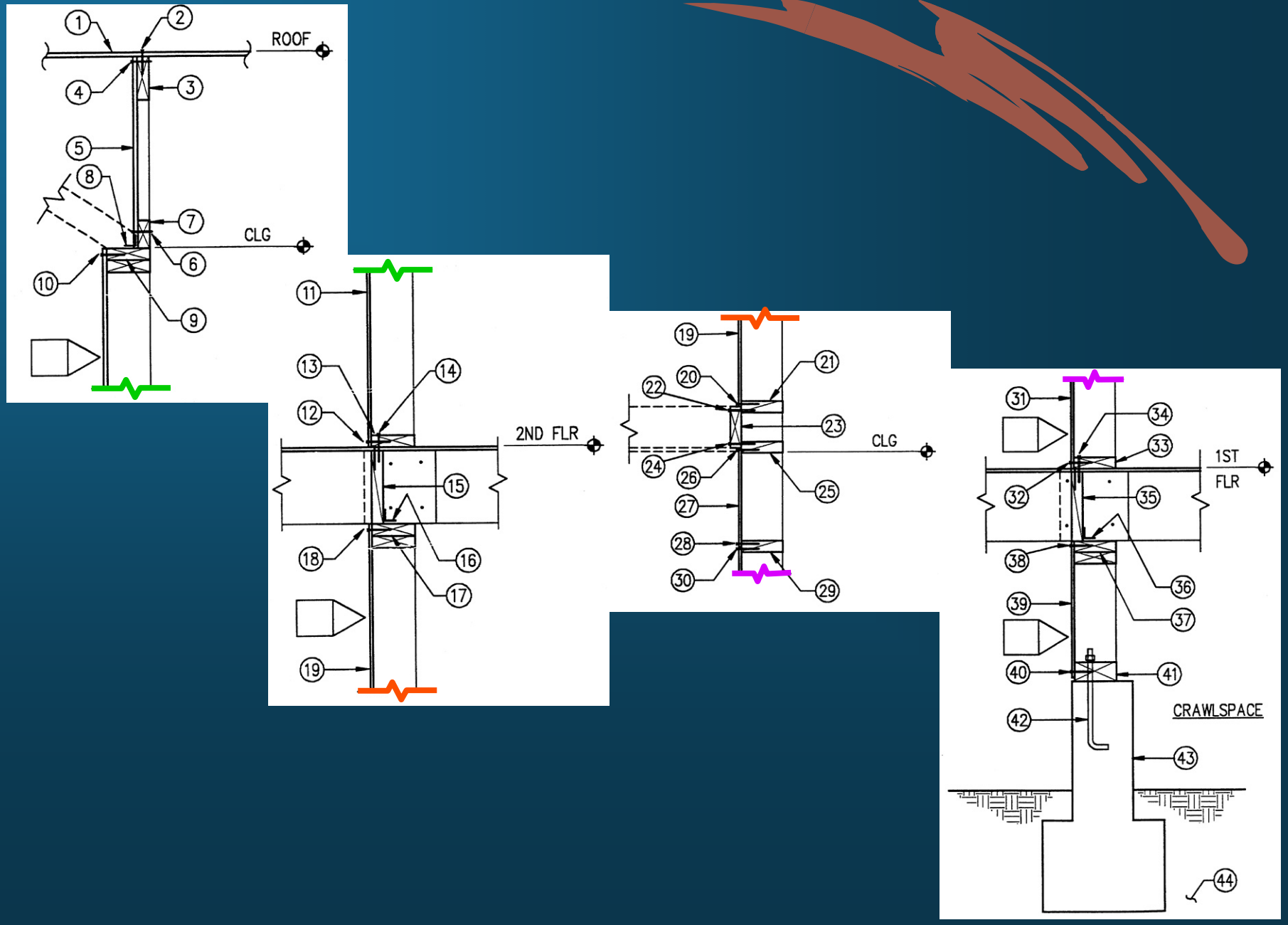
# Untightened Nuts



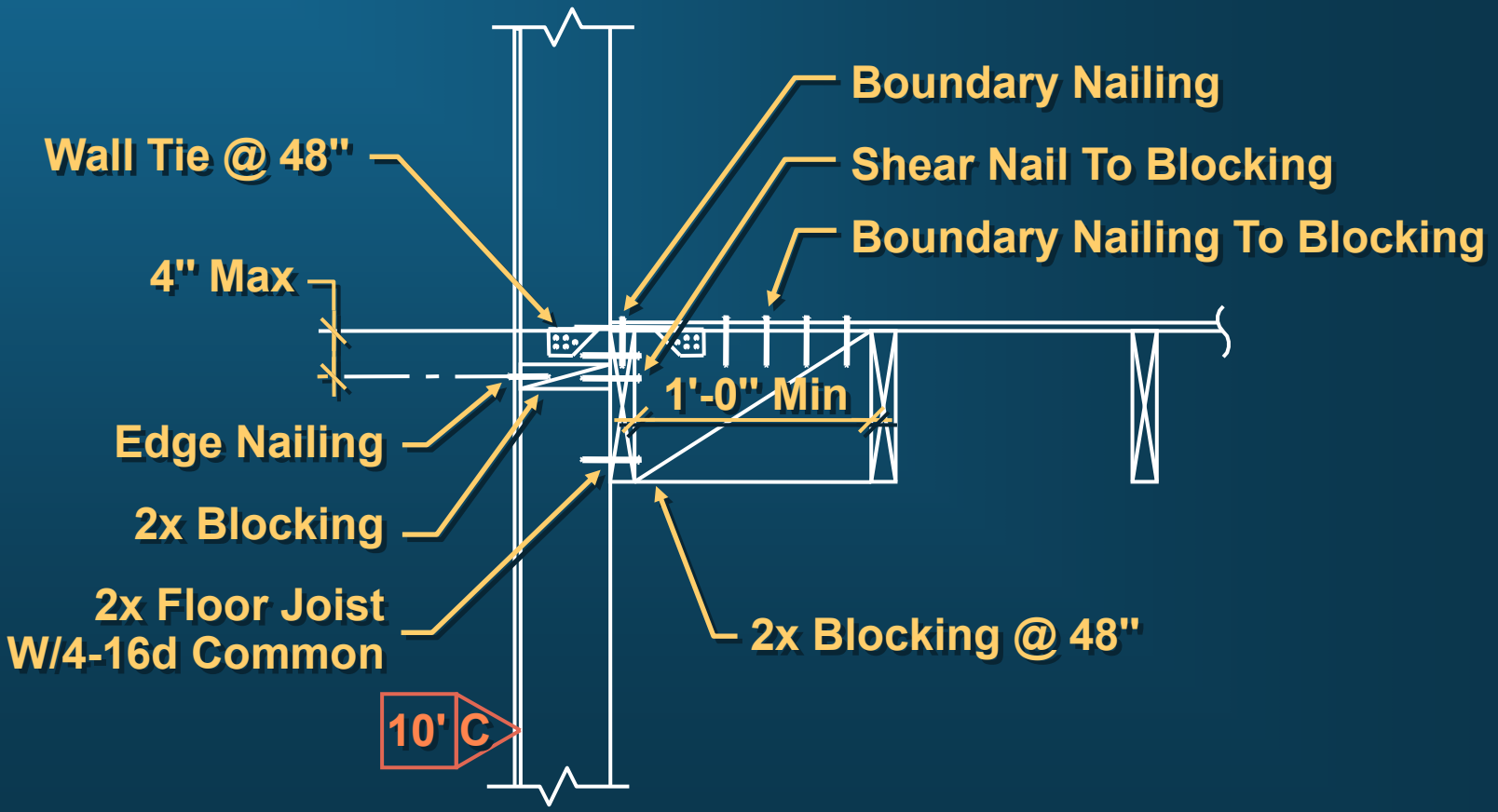
# Wood Connections



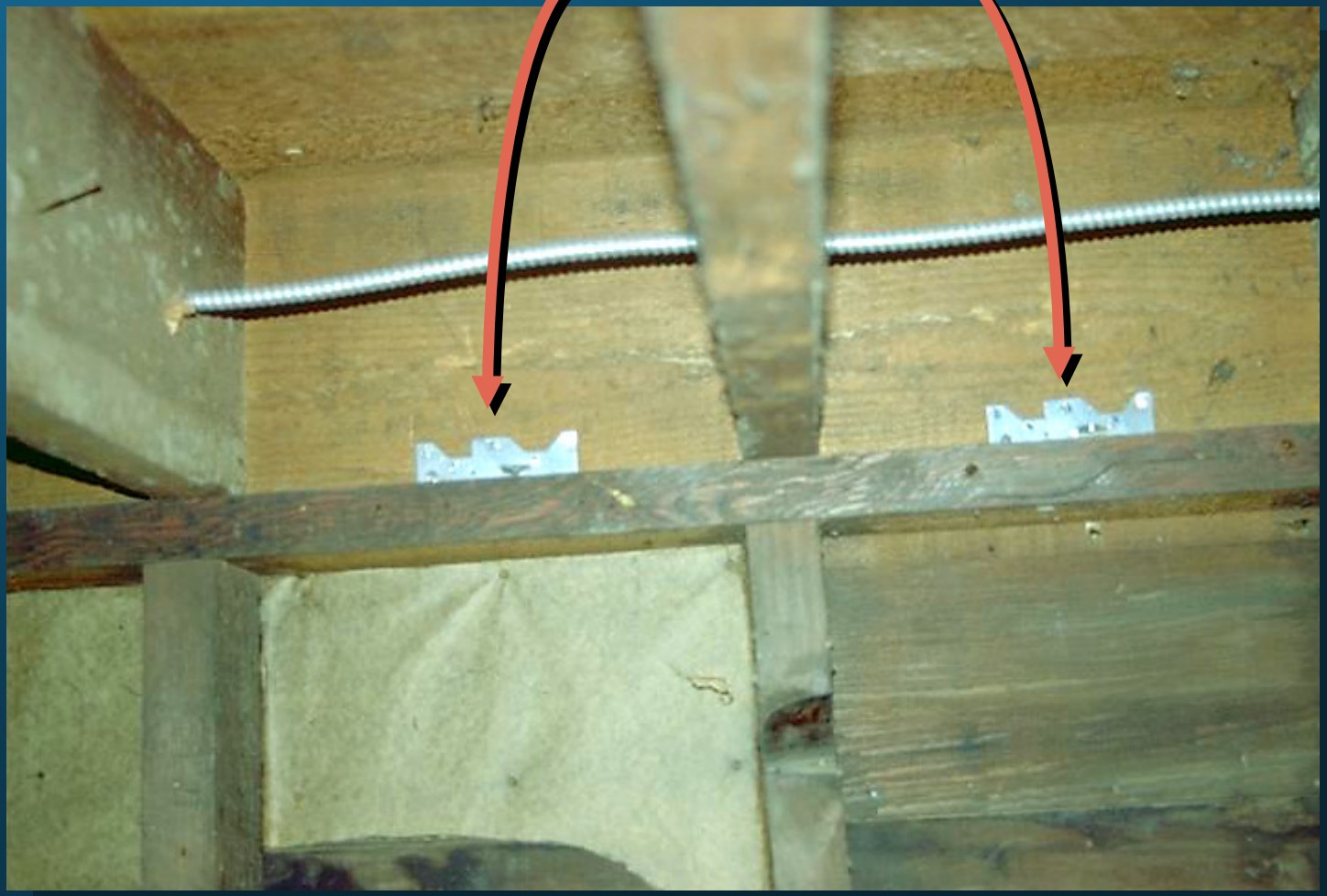



ROOF
CLG
2ND FLR
CLG
1ST
FLR
CRAWLSPACE

# Balloon Framing

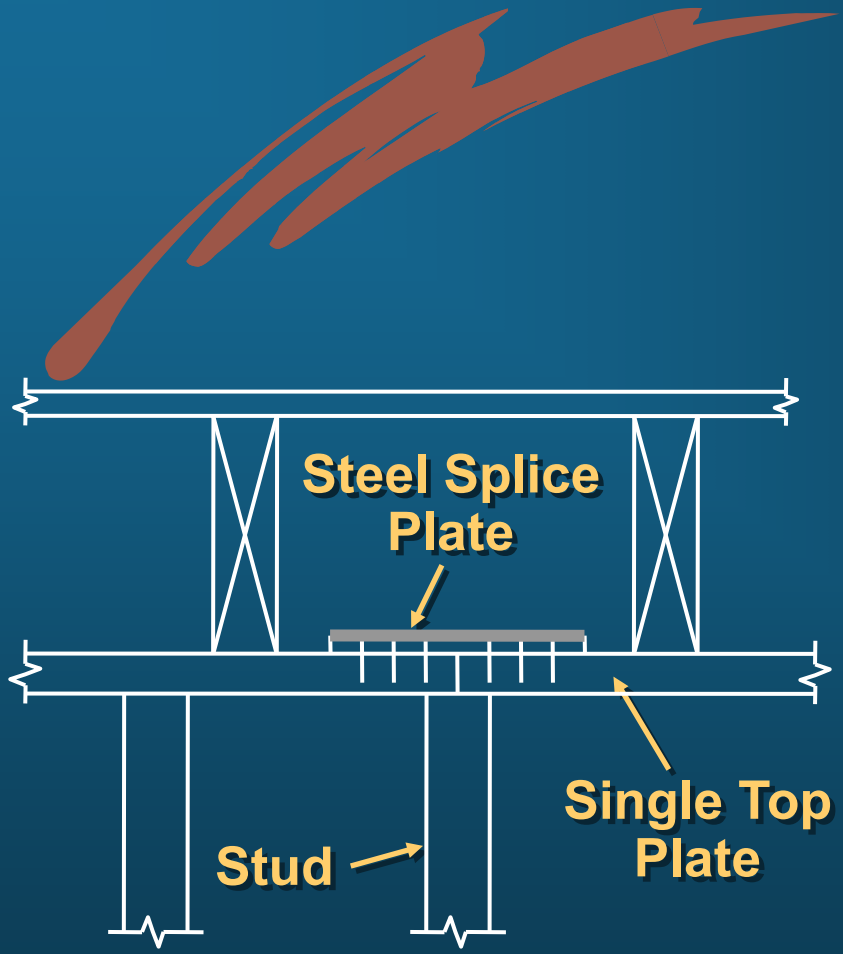


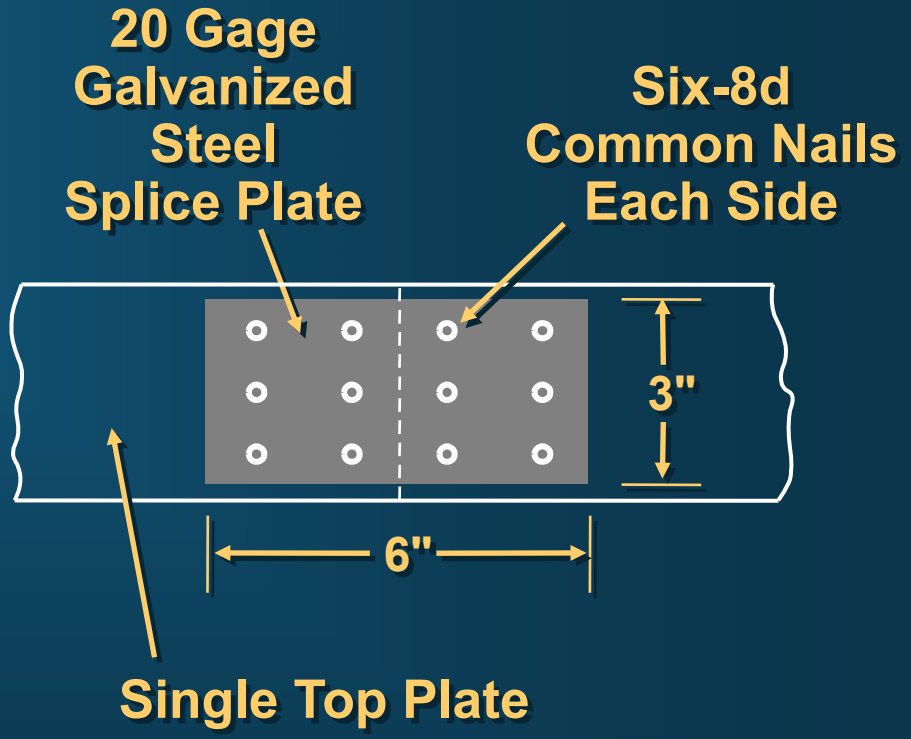
# Connecting the Top Plate With Framing Clips

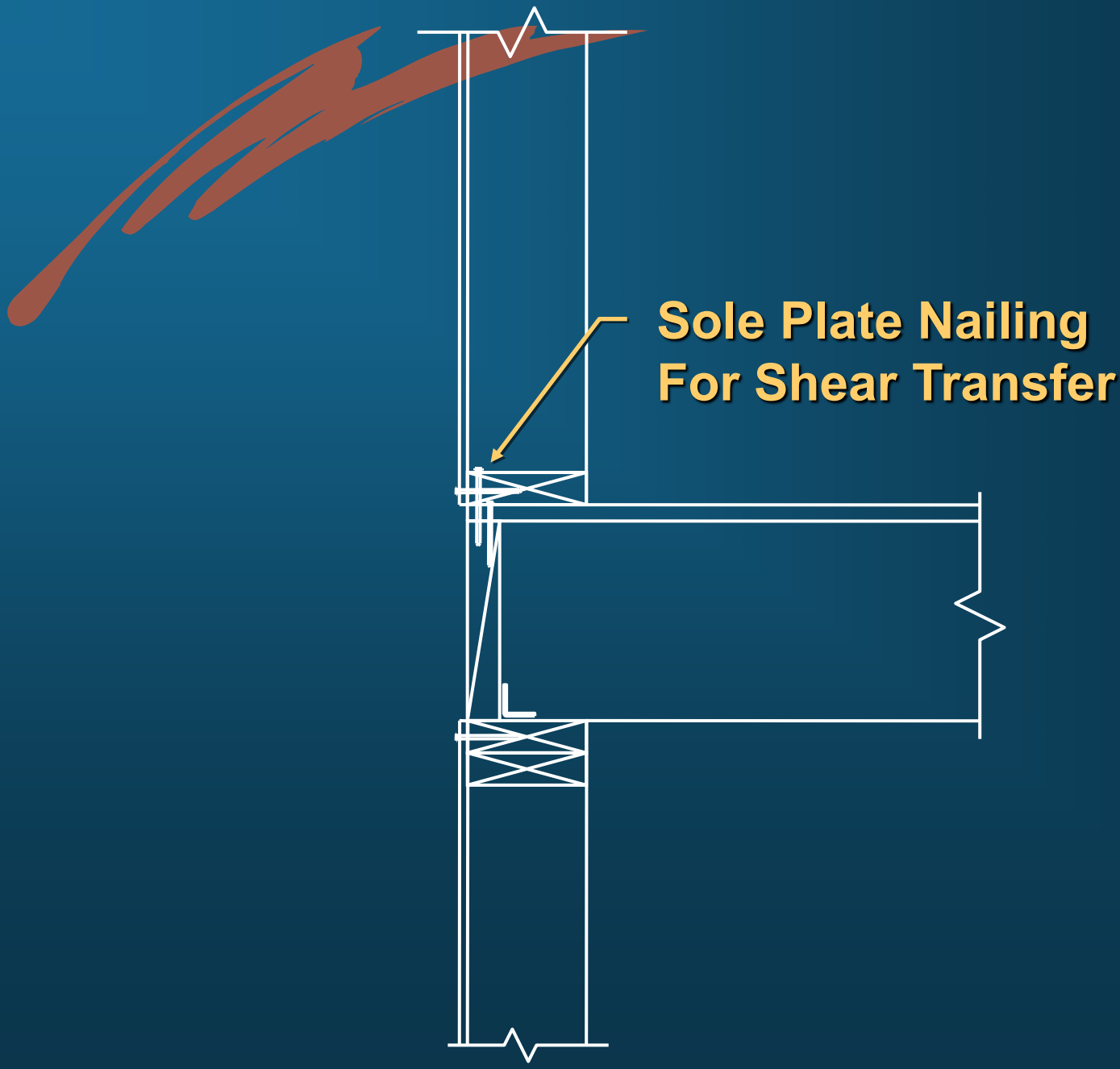


# Palm Nailer




Steel Splice Plate
Stud
Single Top Plate

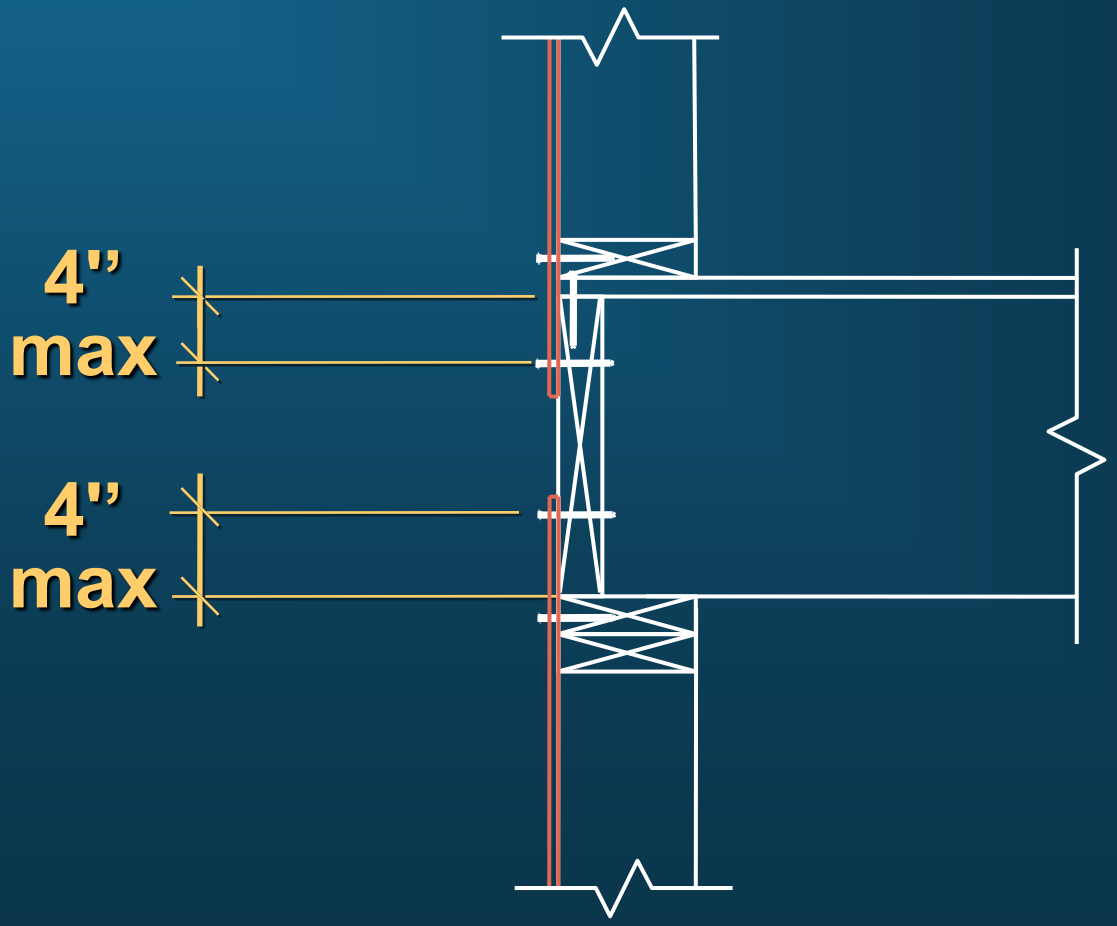

20 Gage Galvanized Steel Splice Plate
Six-8d Common Nails Each Side
3"
6"
Single Top Plate


Sole Plate Nailing
For Shear Transfer

# Double Sole Plates



# Use Longer Sheets of Wood Structural Panels



# Split Sill Plate



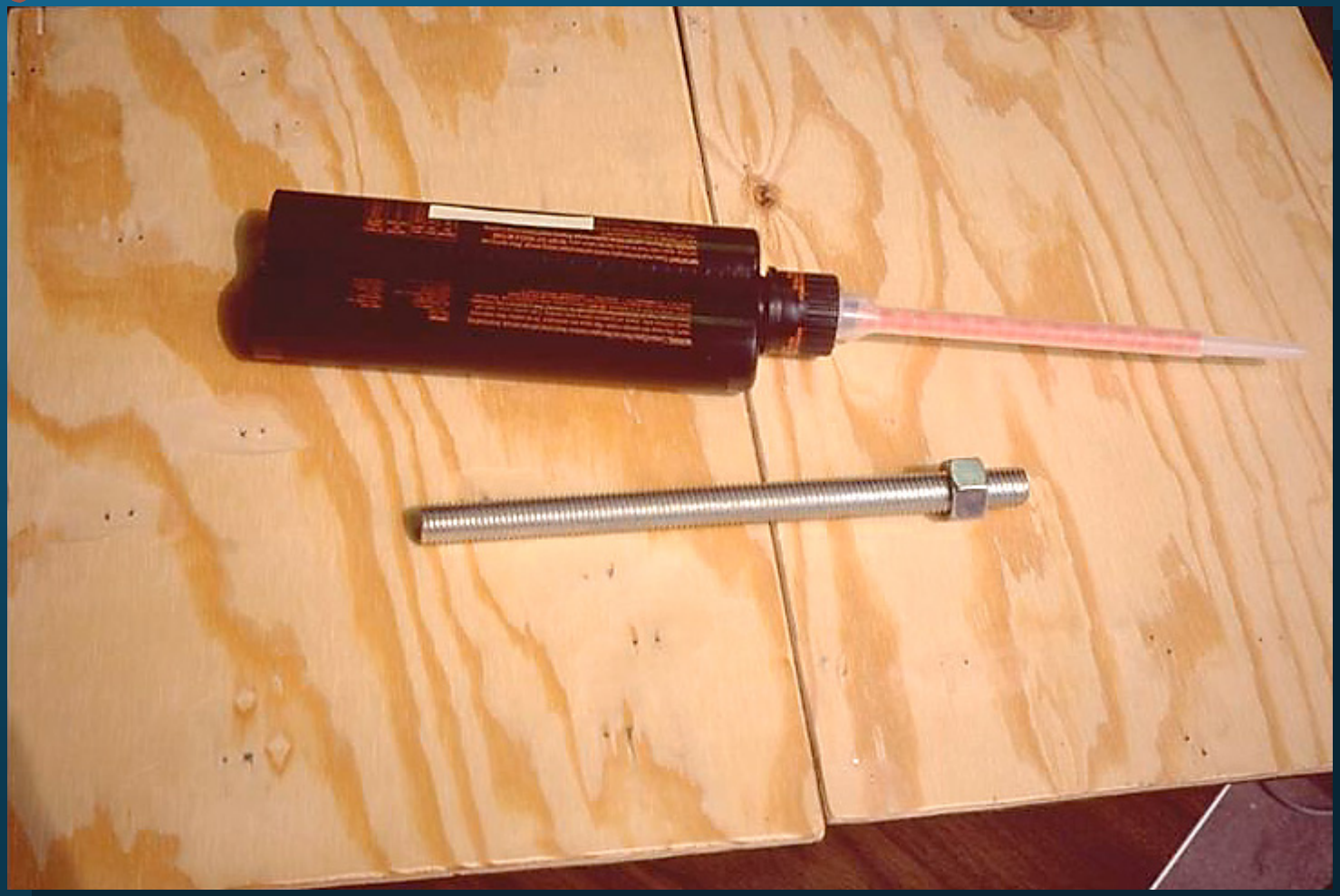
# Special Retrofit Anchors May Be Needed

- Drilled-in anchors
  - Mechanical
  - Adhesive
- Side plates
  - Connect sill plate to foundation

# Mechanical Wedge Anchor



# Adhesive Anchor



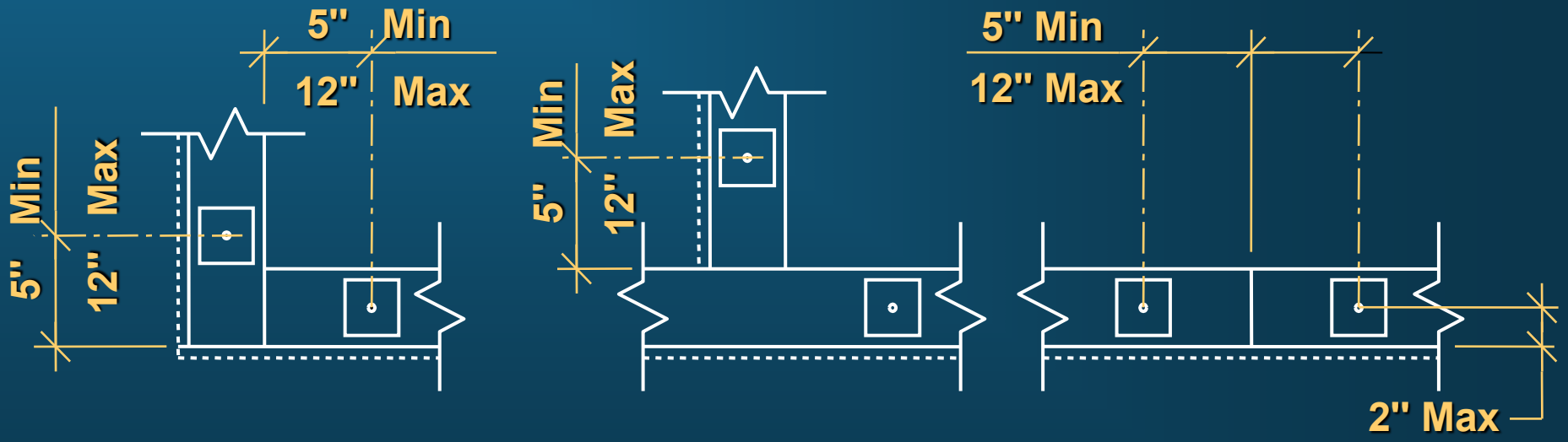
# Side Plate



# Improper Edge Distance in Concre

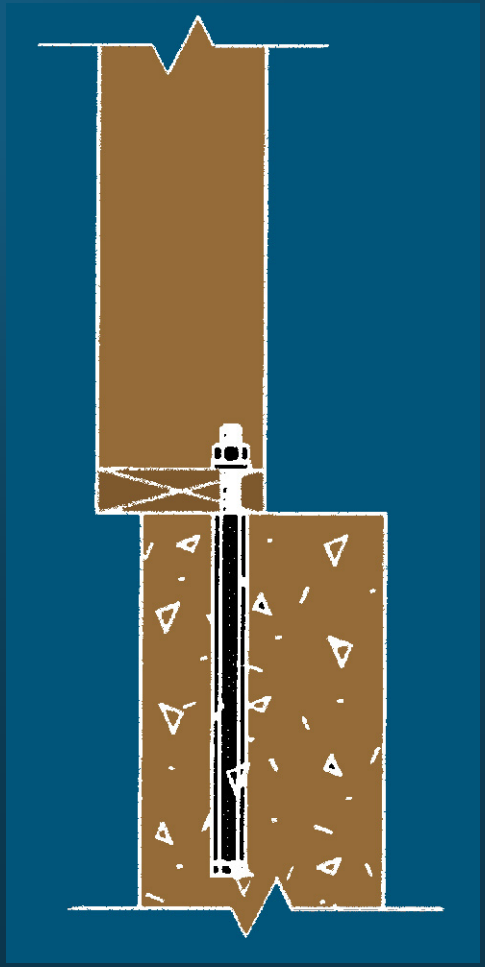


# Proper End Distance for Sill Plate Anchor




Corner Intersection Splice

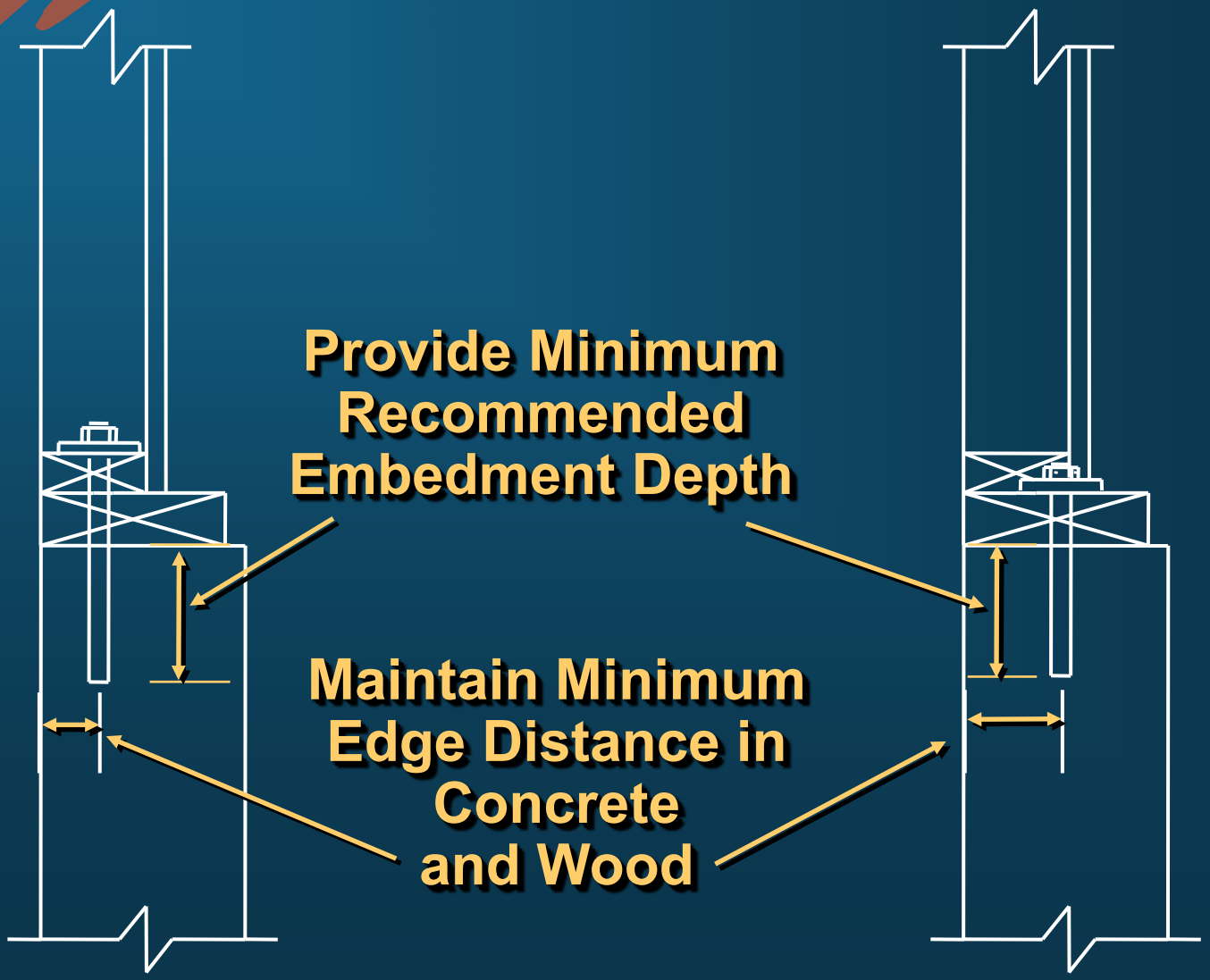
# Misaligned Sill Plate Should be Engineered



# Improper Countersinking



# Anchor the Sill Plate



# Use Square Plate Washers

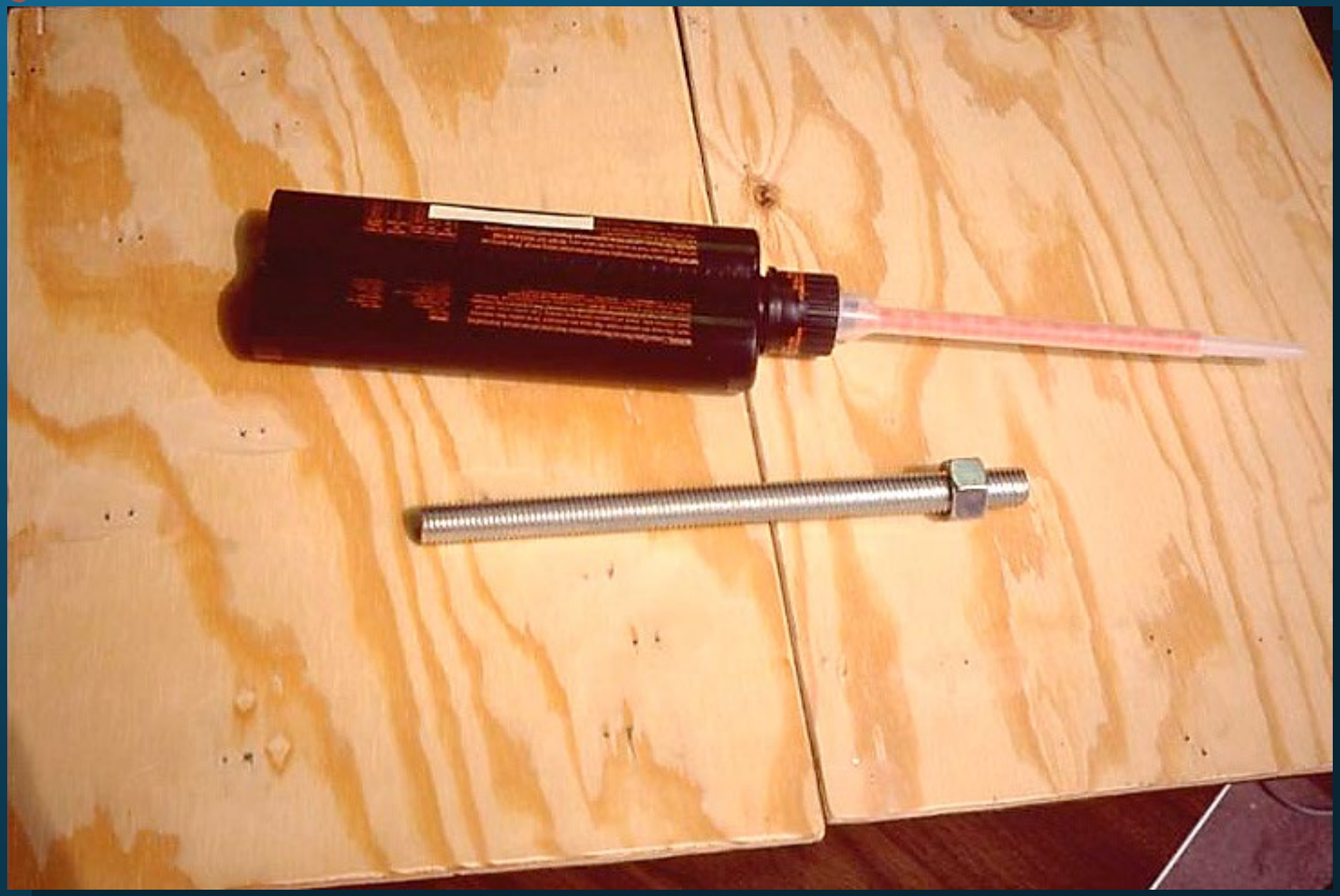


# Installing Mechanical Anchors



- Concrete must be in good shape
- Minimum edge distance must be maintained
- Use required torque and calibrated torque wrench

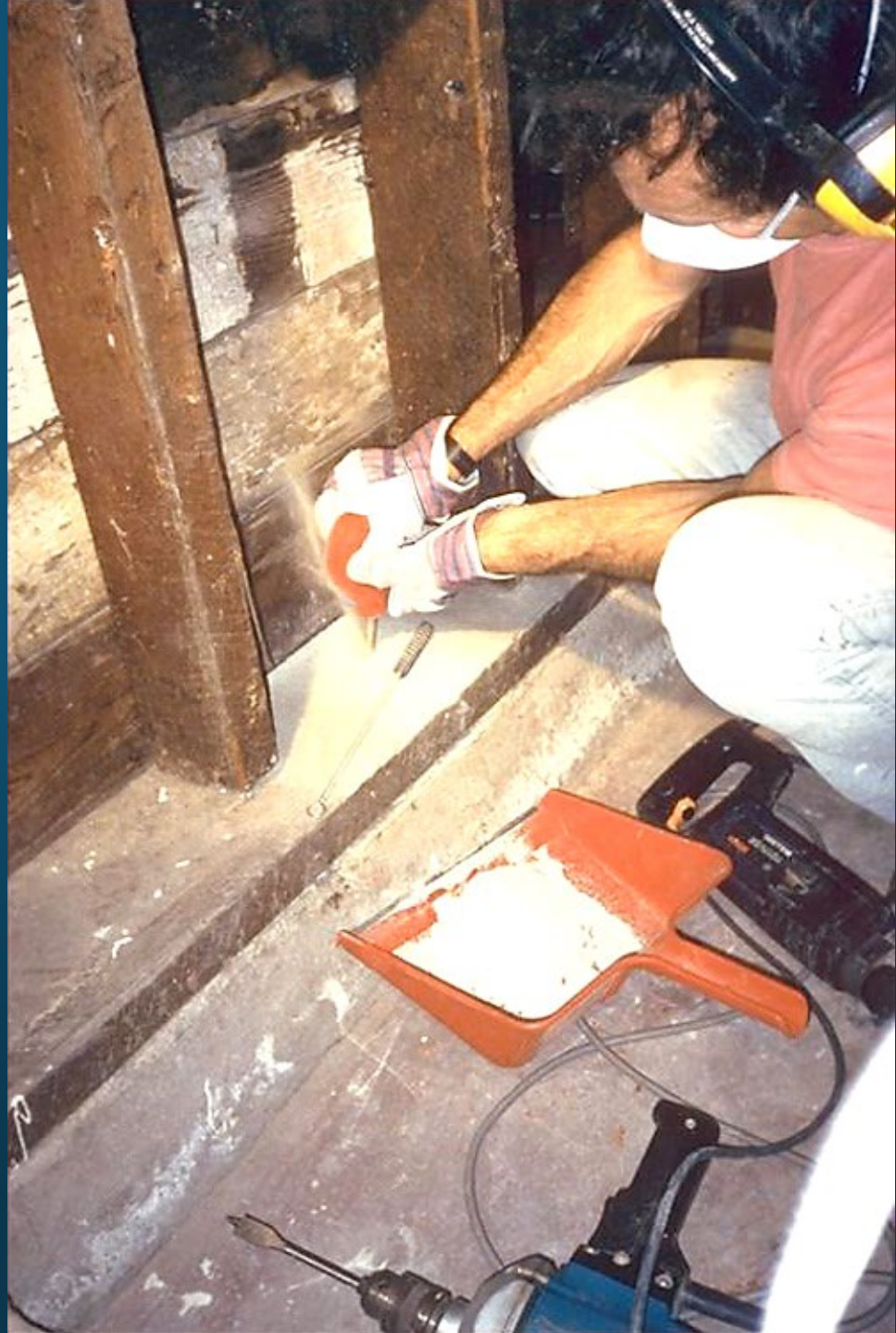
# Installing Adhesive Anchors



# Carefully Clean the Hole



# Blow Out the Fines





- Use threaded rod
- Fill the hole with adhesive
- Install rod with washer and nut attached
- Cure before tightening

# Installing Side Plates



- Lag screws require pre-drilling with 2 different diameter bits
- DO NOT overtighten
- DO NOT drive with hammer



# Most Important

- Understand the load path
- Maintain a **complete** and **continuous** load path from top to bottom

# Foundations

## Section 5

# Partial Foundation



# Post And Pier Foundation



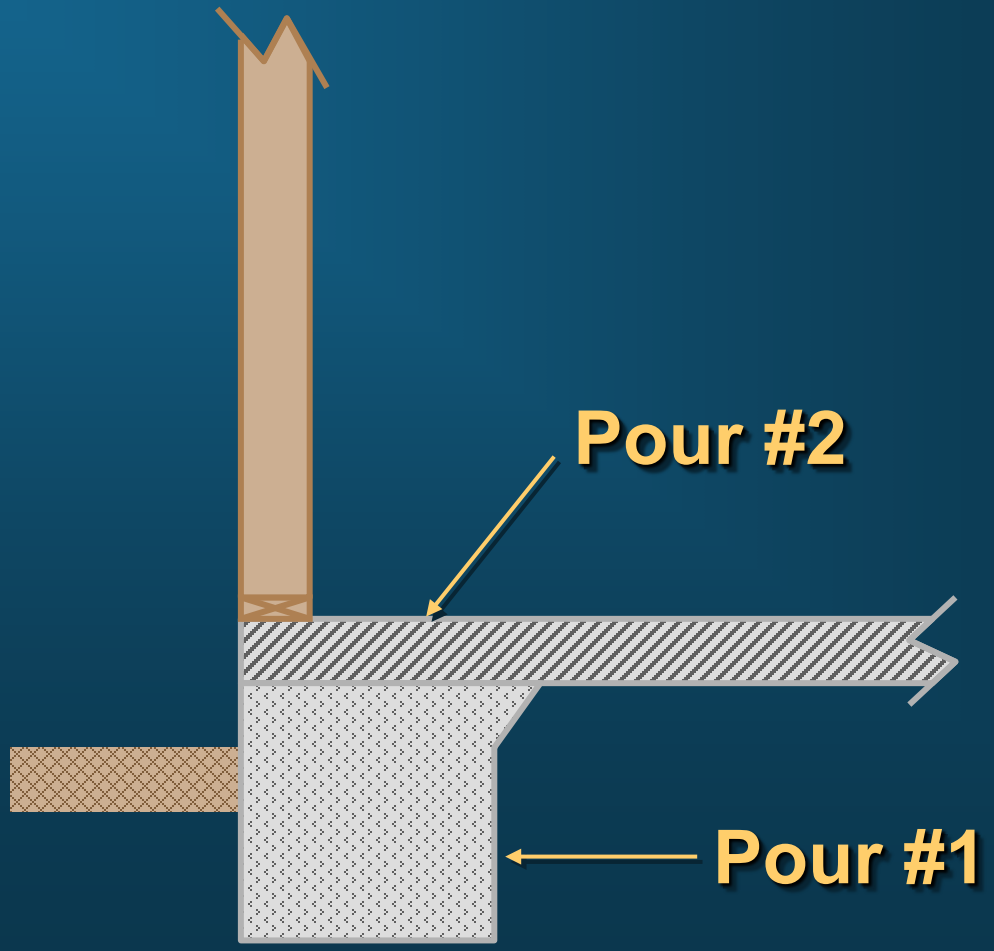
# Interior Posts and Girders



# Continuous Interior Footing



# Two Pour System



# Failure of Two Pour Joint



# Foundation Materials

- Concrete
- Concrete Block
- Brick
- Stone

# Unreinforced Brick Foundation Wa



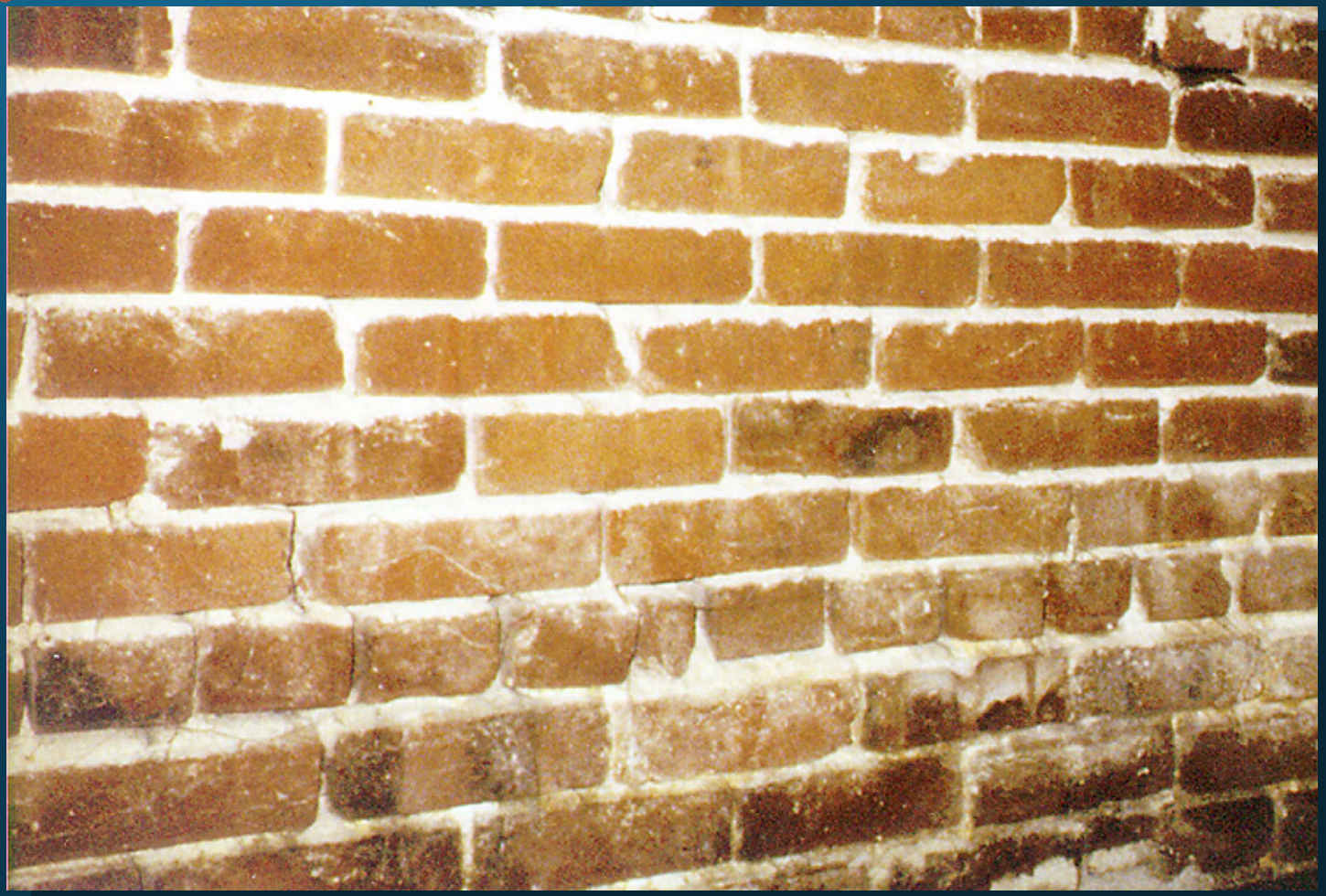
# Stone Foundation



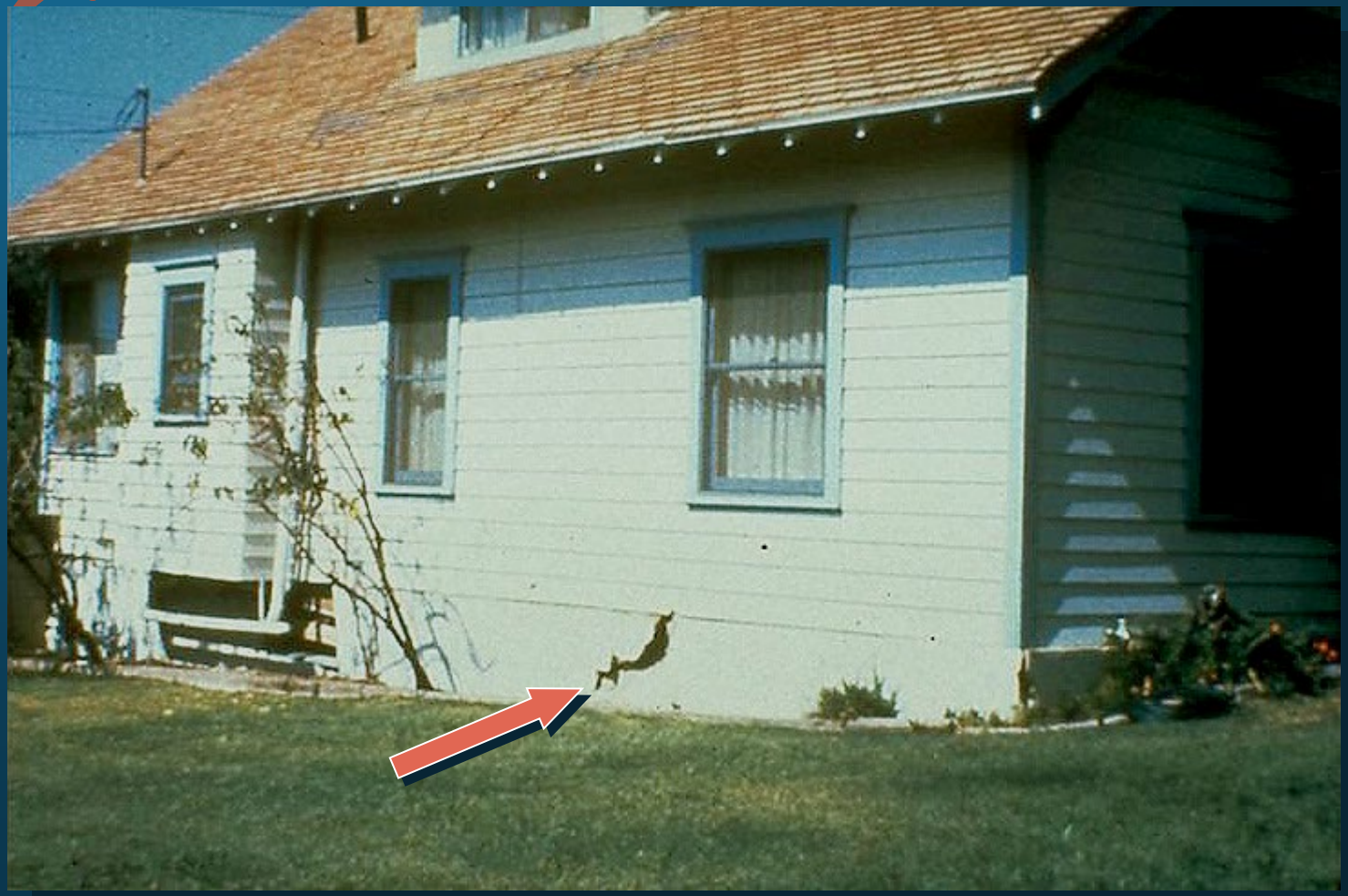
# Check Foundation Condition

- Deterioration
- Cracking

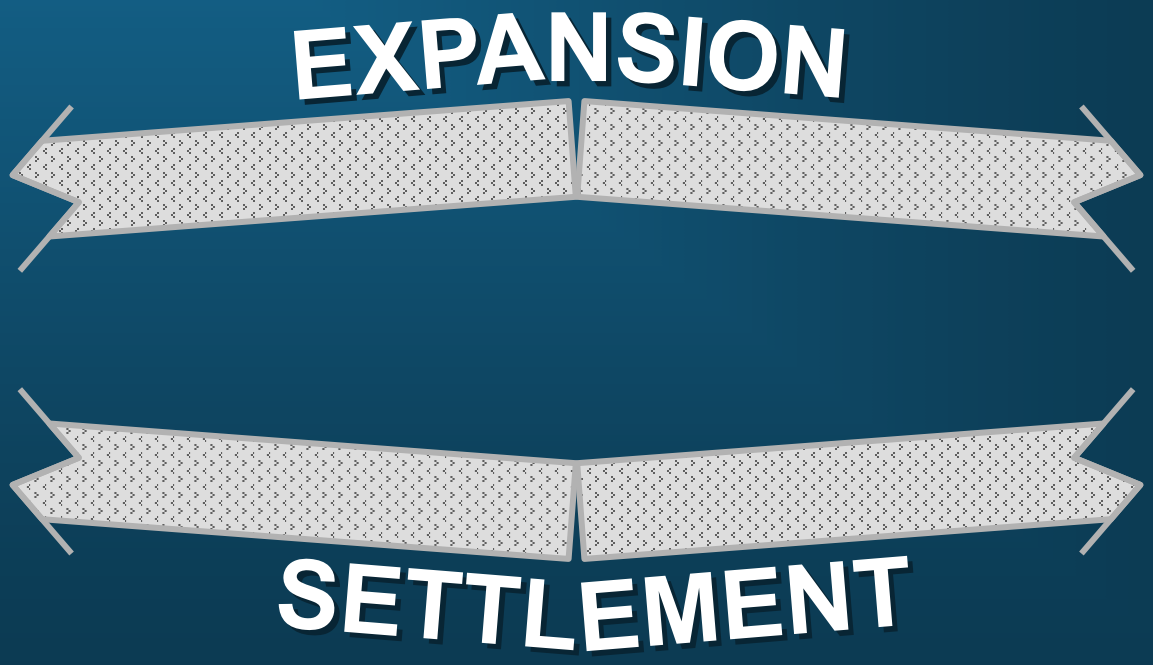
# Deteriorated Mortar Joints



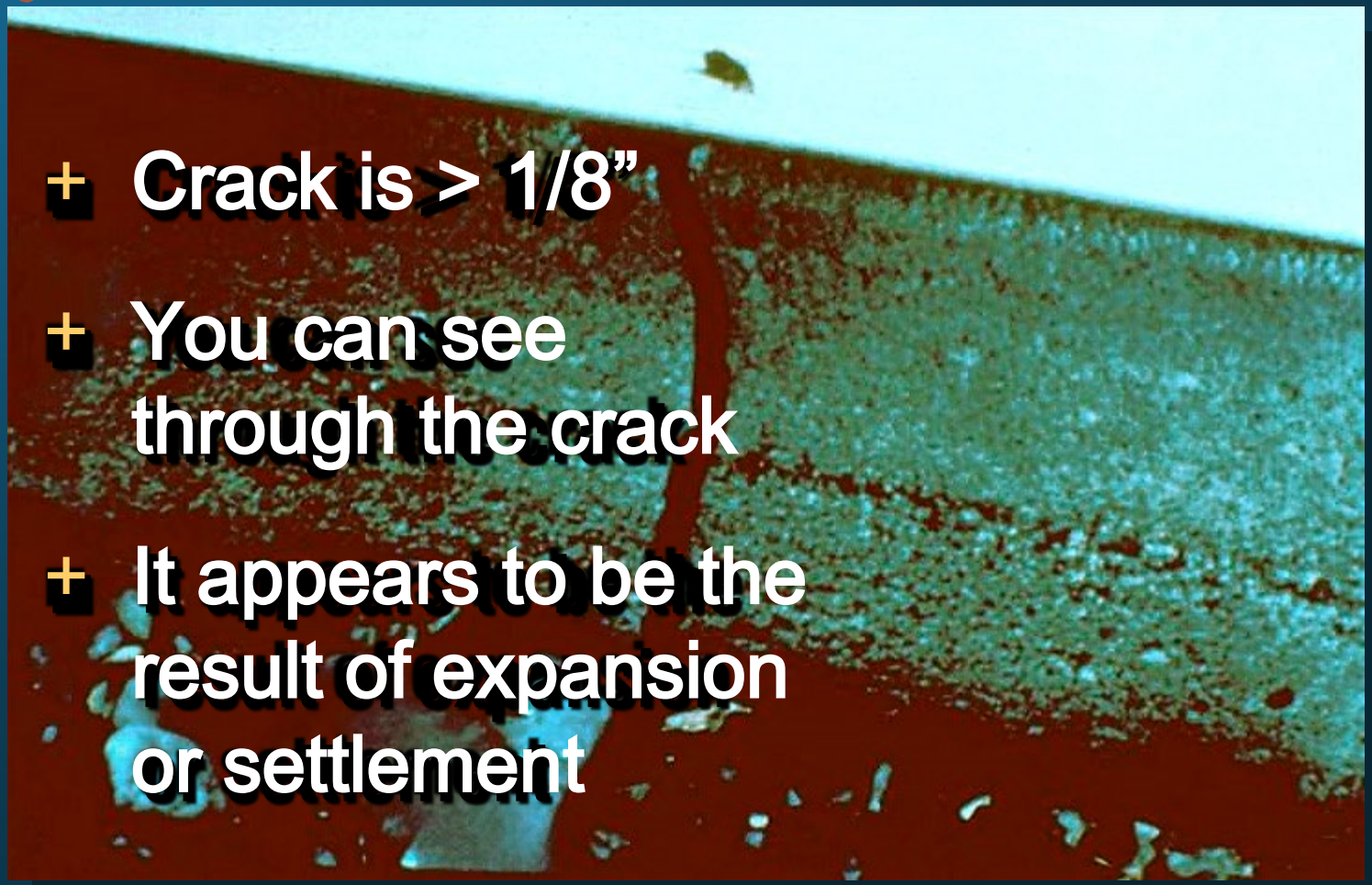
# Foundation Crack



# What Causes Cracking?

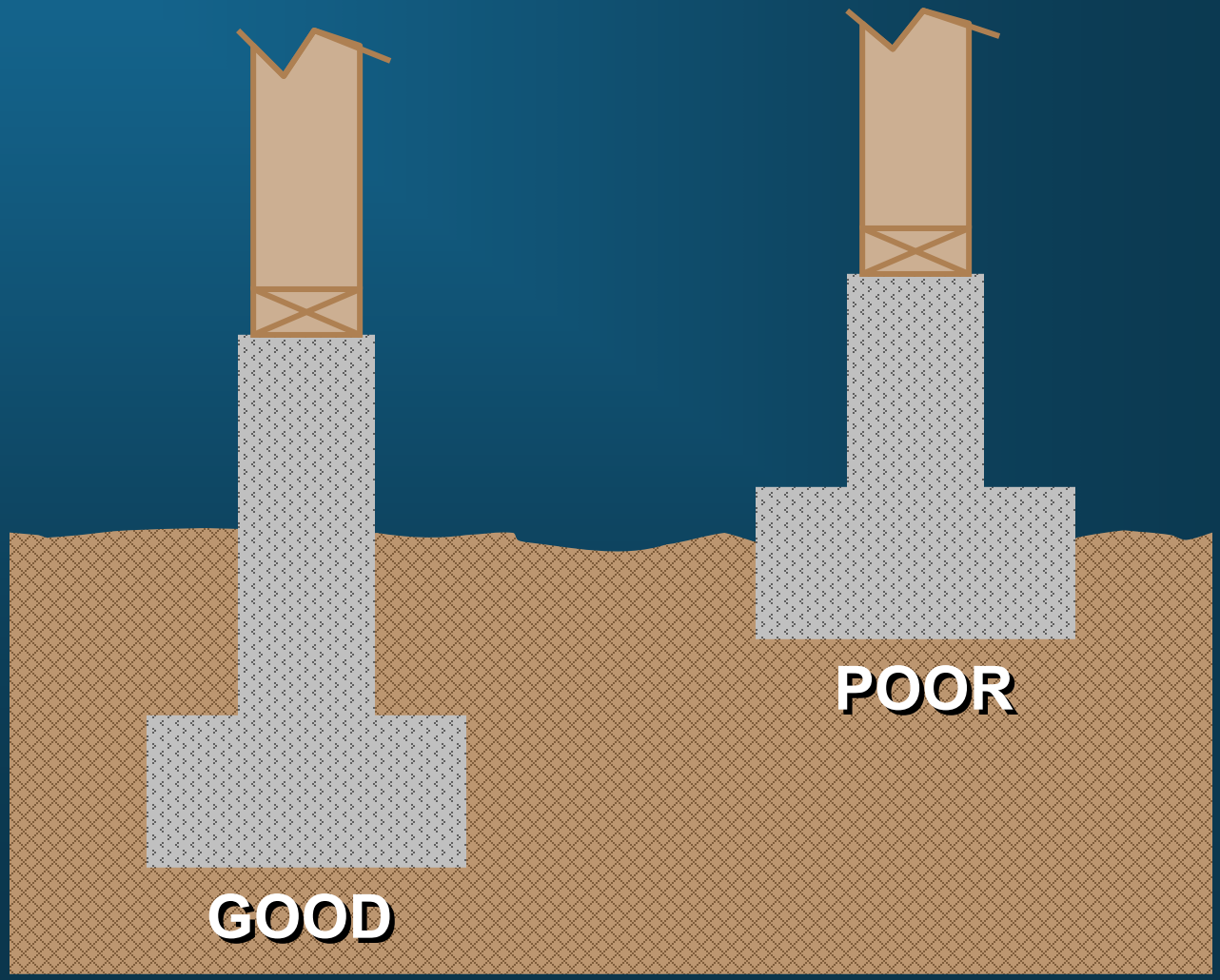


# Consult a Professional When…

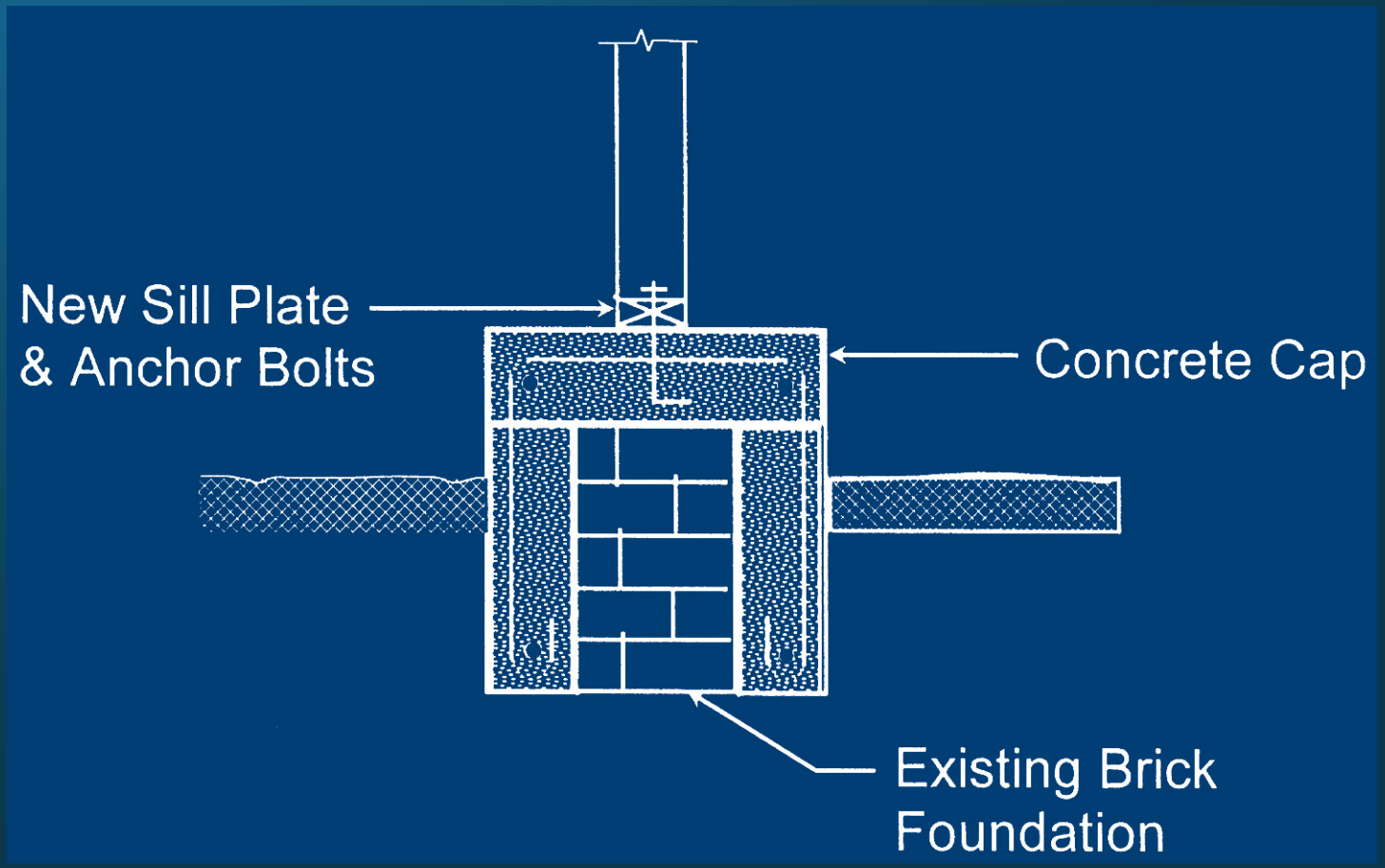


- Crack is > 1/8”
- You can see through the crack
- It appears to be the result of expansion or settlement

# Foundation Embedment



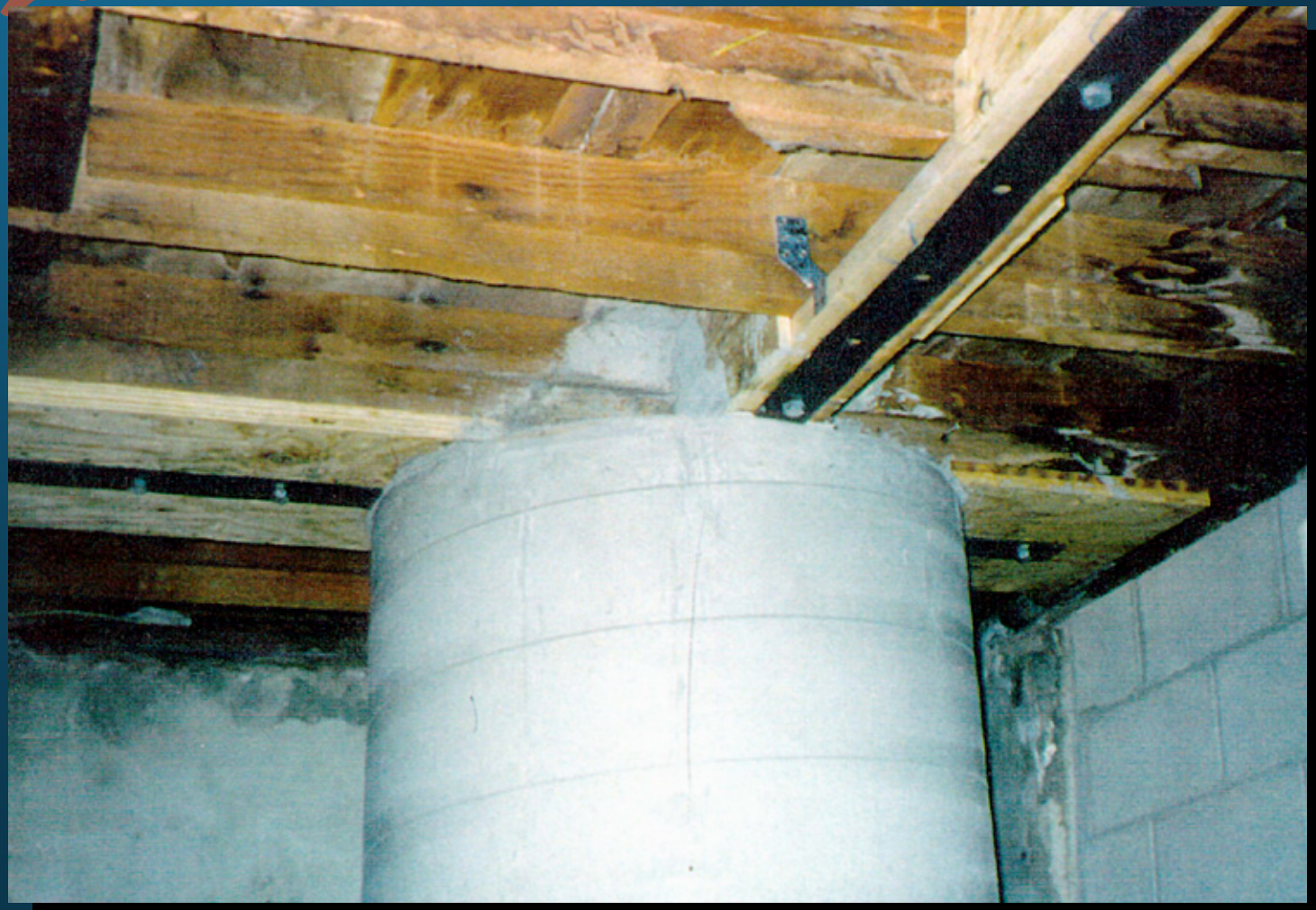
# Capping Existing Foundations



# Foundation Replacement



# Parallel System



# Retrofitting Post-and-Pier Type Houses

Section 6

# Why Do Earthquakes Damage These Houses?

- No sheath wall below 1st story
- No adequate foundation under perimeter walls

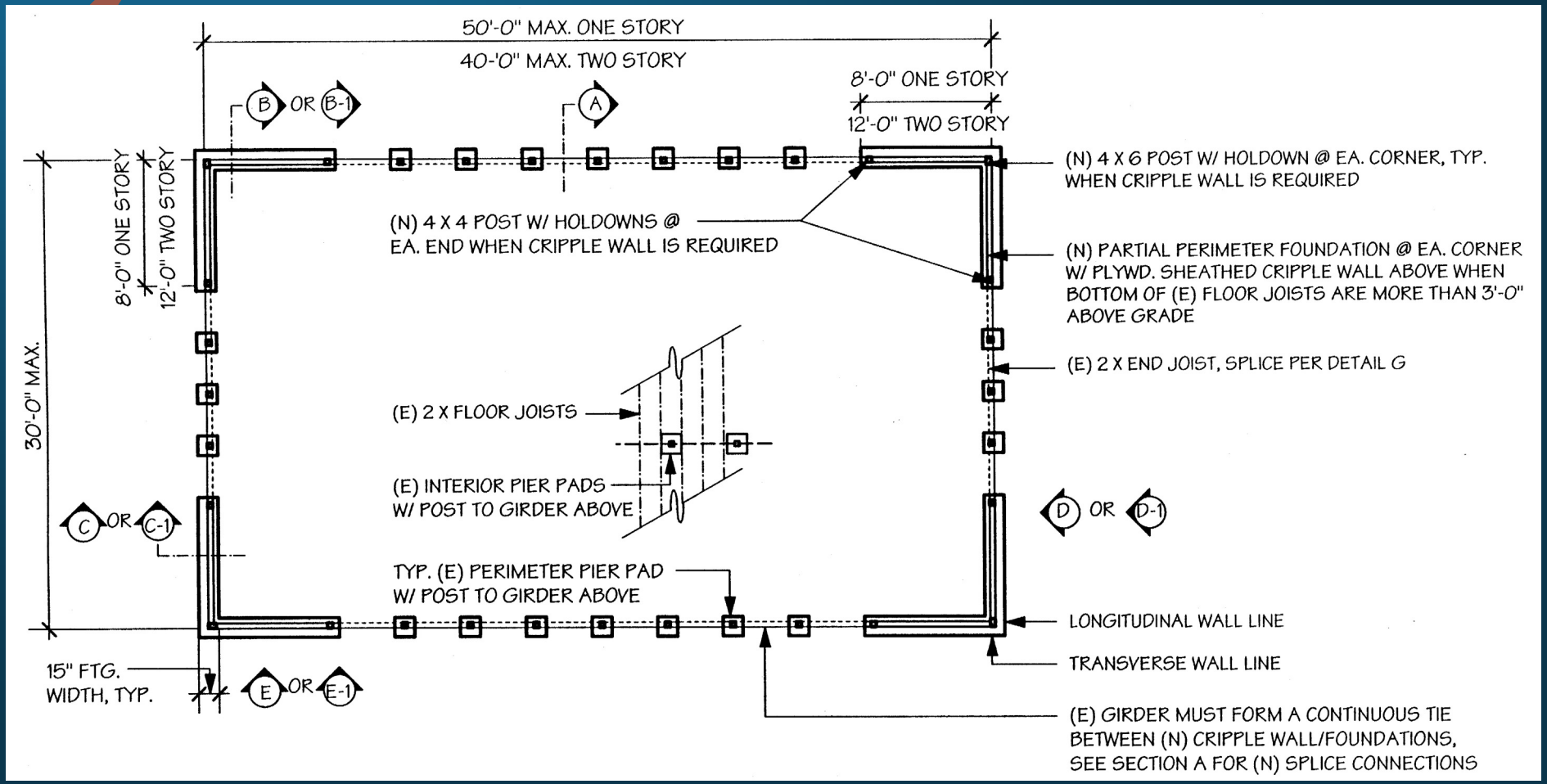
# Typical Post-and-Pier House

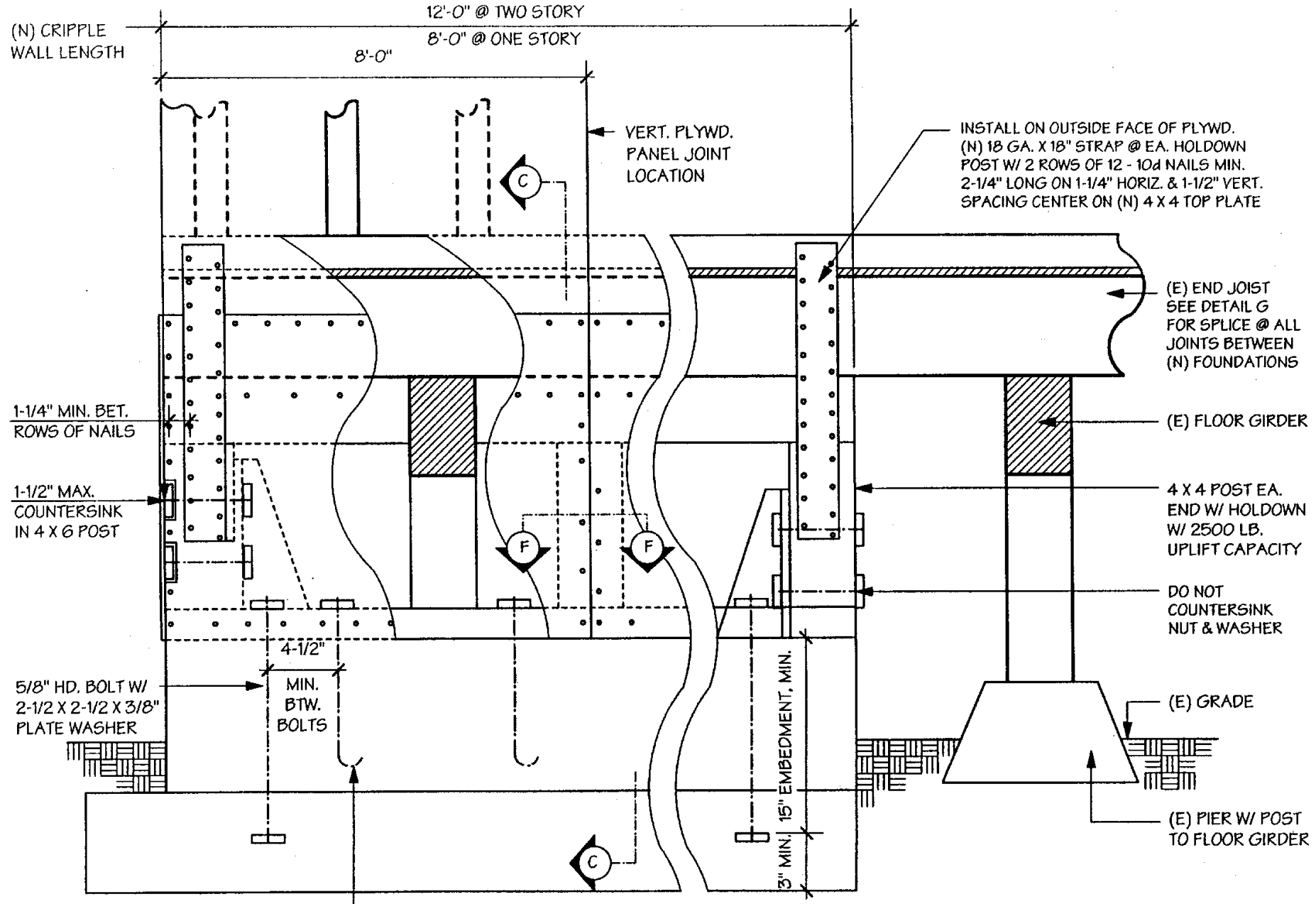


# Braced Posts



# Plan View:
# Partial Perimeter Foundation Syste





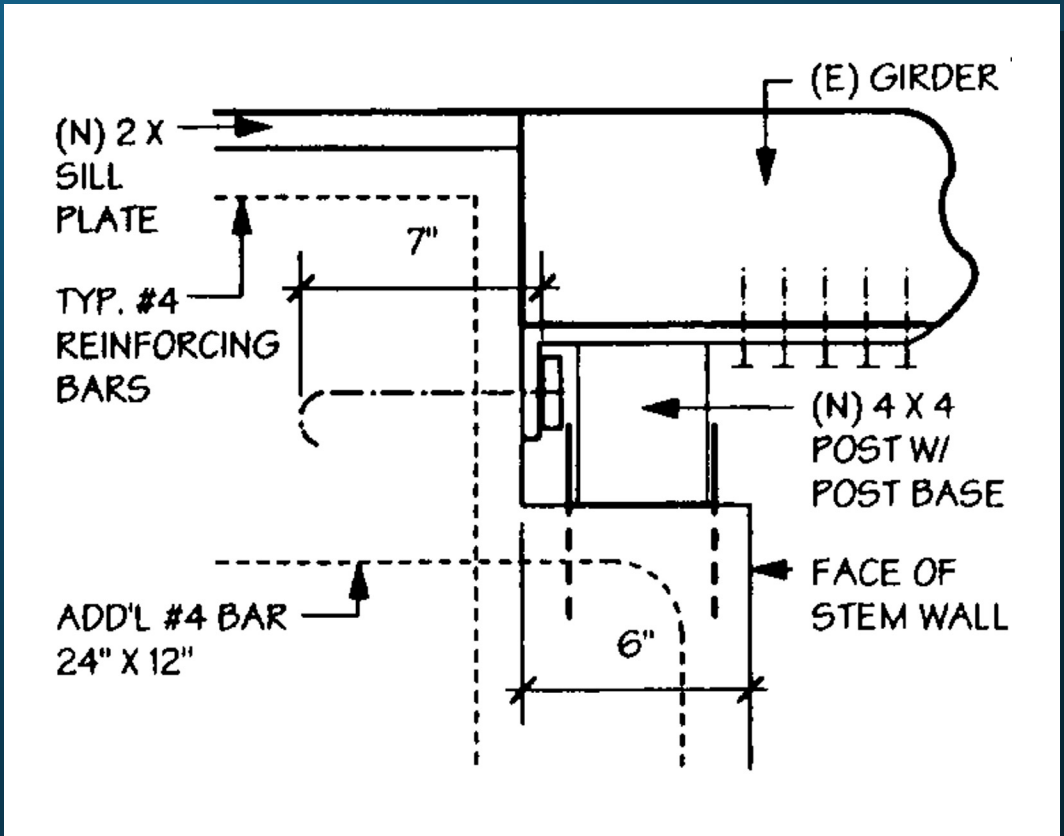

# ELEVATION ALONG (N) FOUNDATION/CRIPPLE WALL WHERE (E) FLOOR JOIST ARE PARALLEL TO WALL

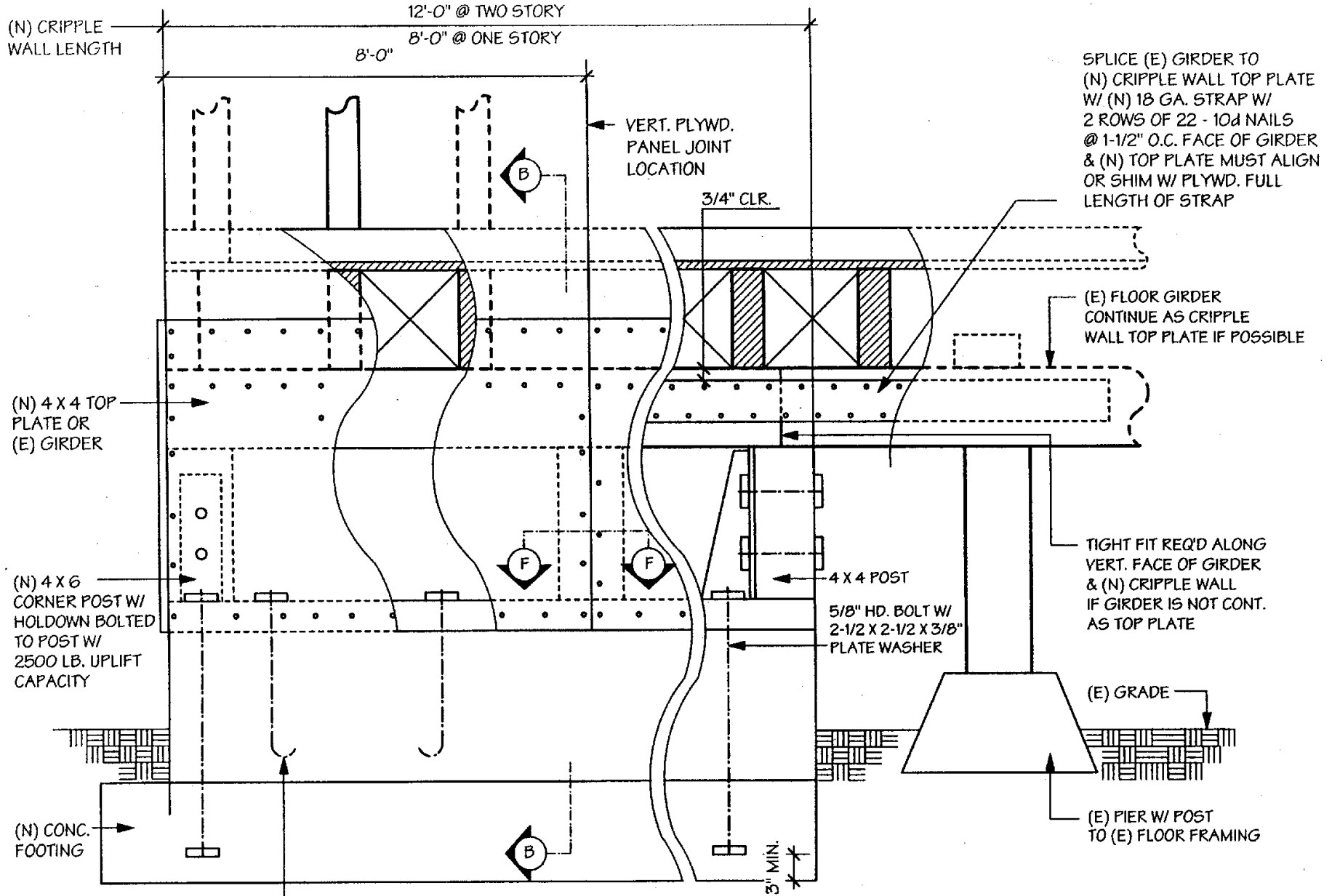
D

# New Metal Strap Reinforcement



# Girder Connection to New Foundation Stem Wall

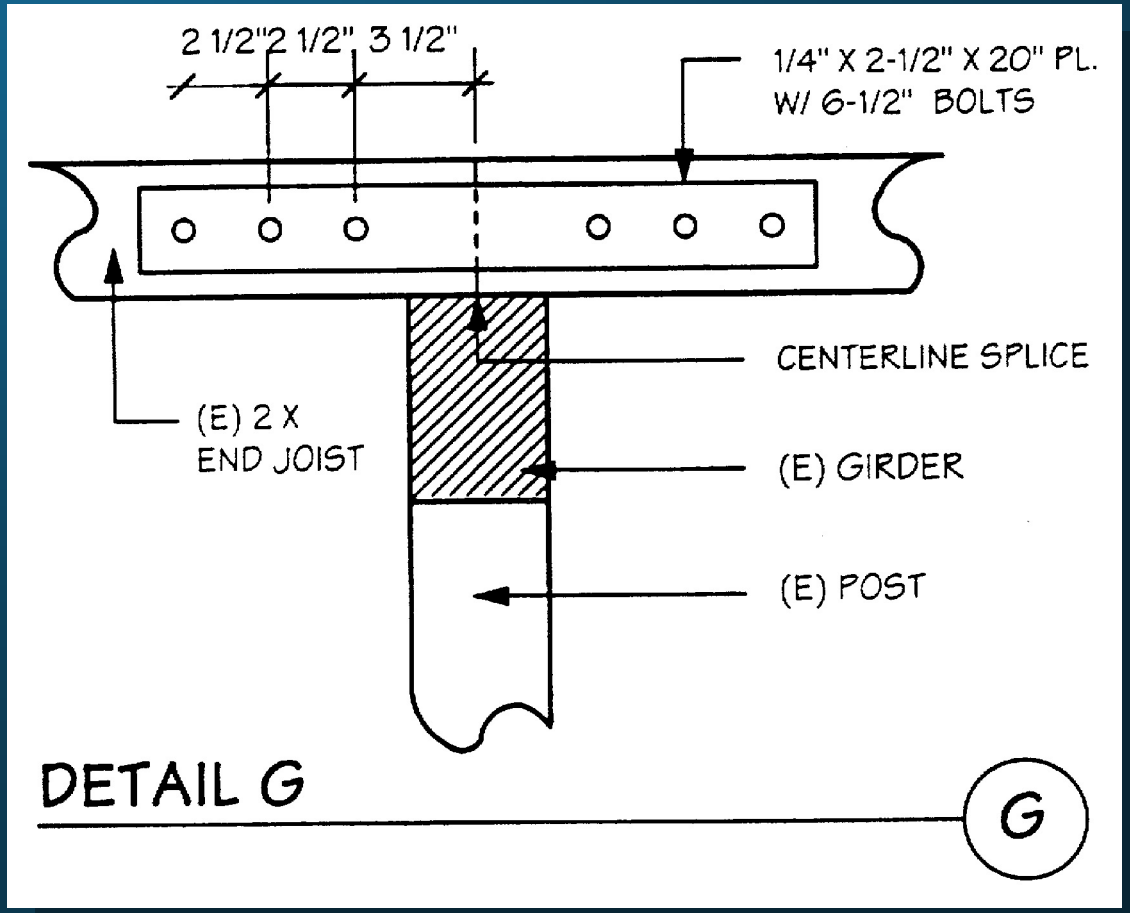




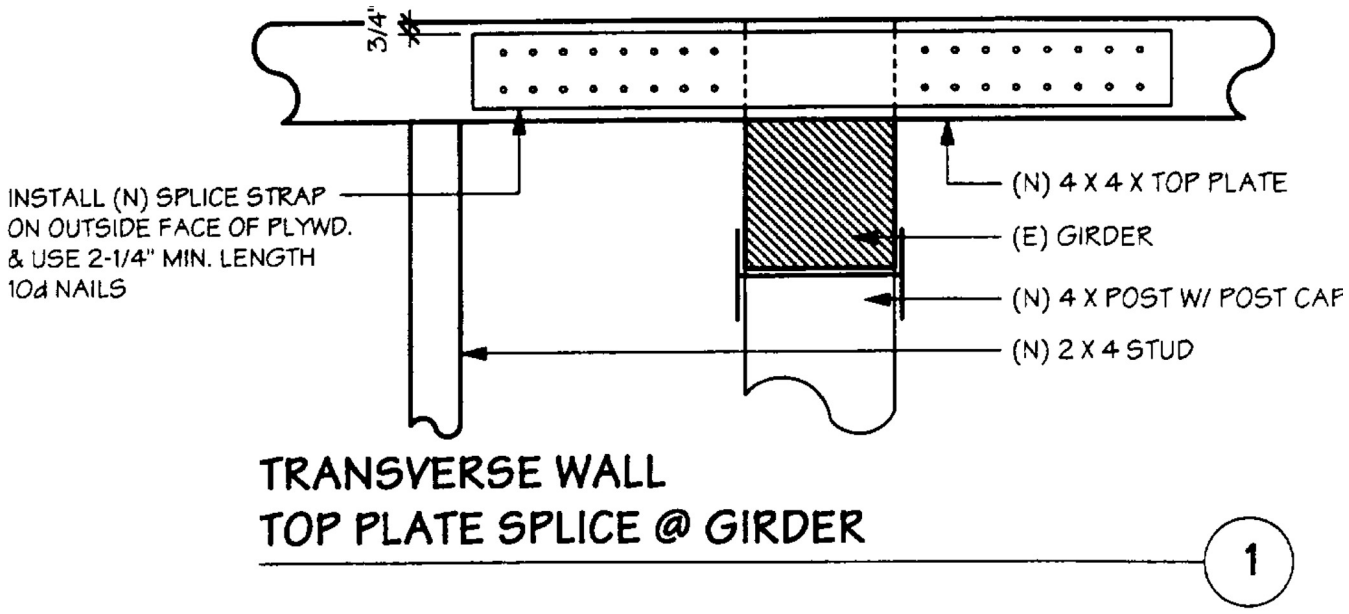

# ELEVATION ALONG (N) FOUNDATION/CRIPPLE WALL WHERE (E) FLOOR JOIST ARE PERPENDICULAR TO WALL

E

# Strap for Joist Splice



# Strap for Plate Splice



# Important

- Evaluate existing conditions
- Hire professional if needed
  - Sloping site
  - Home over two stories
  - Liquefaction or plastic clay soils
  - Near an earthquake fault.

# Partial Perimeter Retrofits Require Attention to Detail

- Require much more work
- Install shoring
- Anchor bolts & hold downs
- May not need cripple wall
- Building inspections

# Non-Structural Elements

Section 7

# Reinforced Chimney



# Braced Chimney Failure



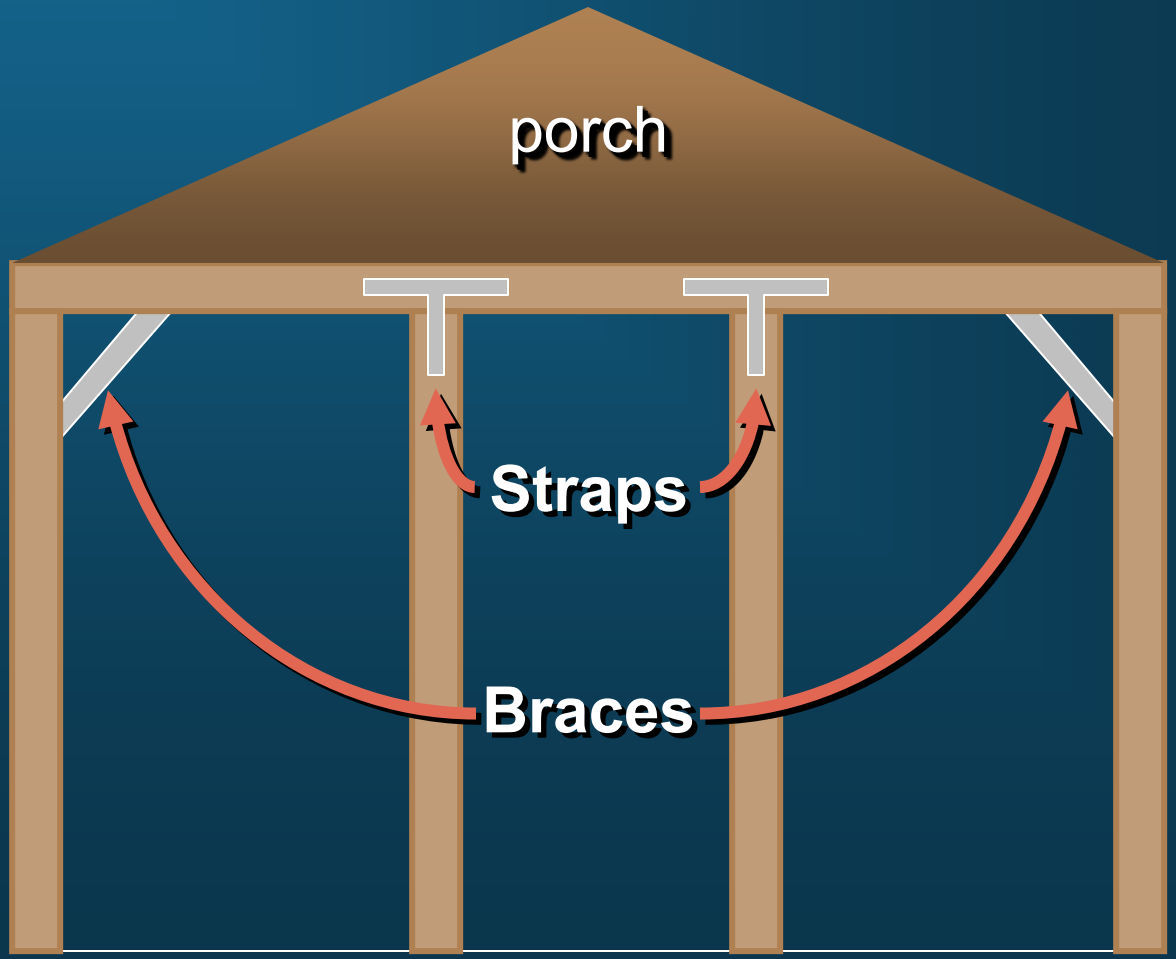
# Lightweight Stud-Framed Chimney



# Collapsed Porch Roof



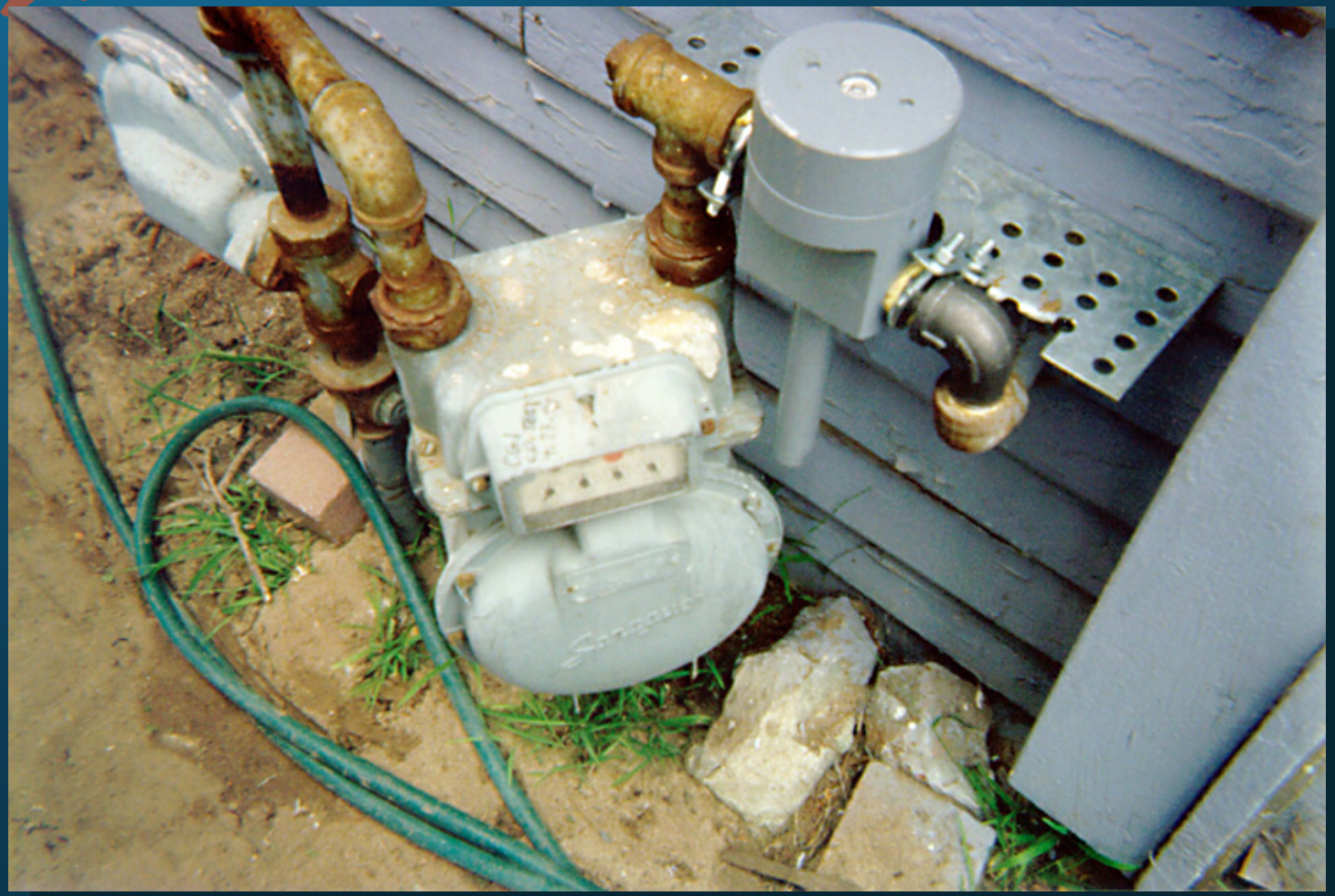
# Use Straps and Diagonal Braces to Increase Strength of Posts



# Brick Veneer



# Automatic Shut-Off Valve



# Water Heaters Tip Easily During Earthquakes



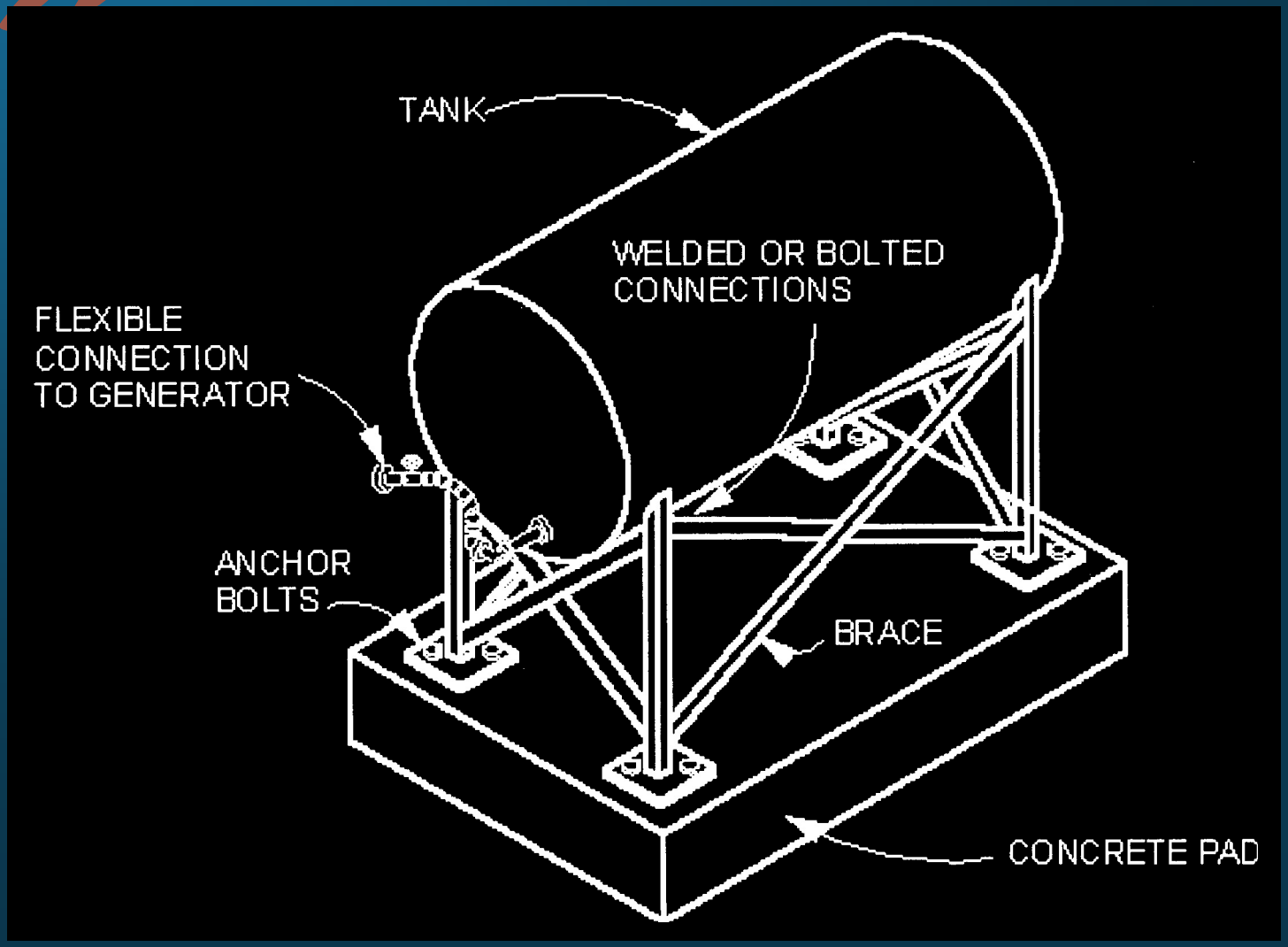
# Braced Water Heater



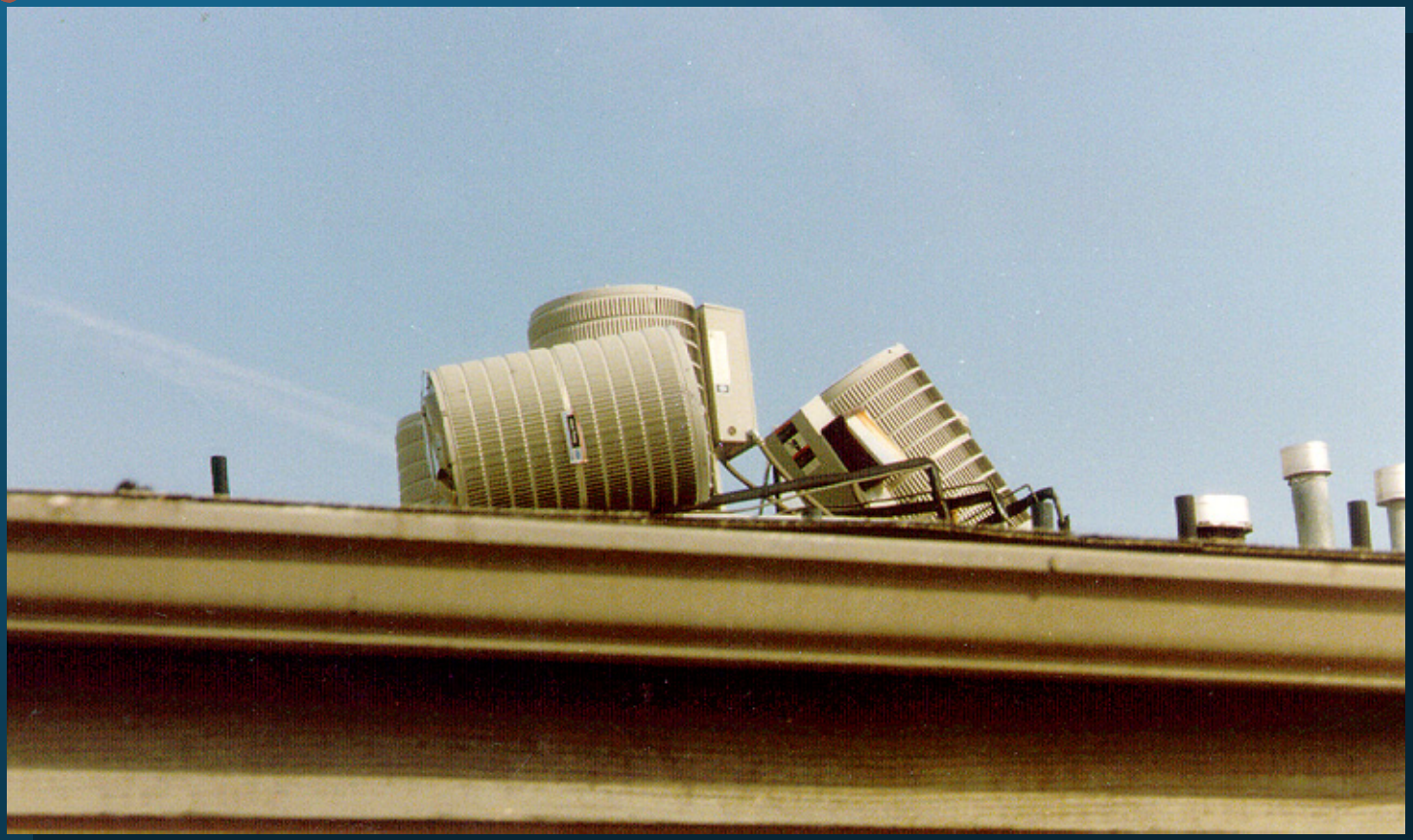
# Pre-Packaged Bracing System



# Tank Bracing



# Air Conditioner Collapse



# Bureau Toppled



# Broken Glass in Kitchen



# Safety and Legal Issues

Section 8

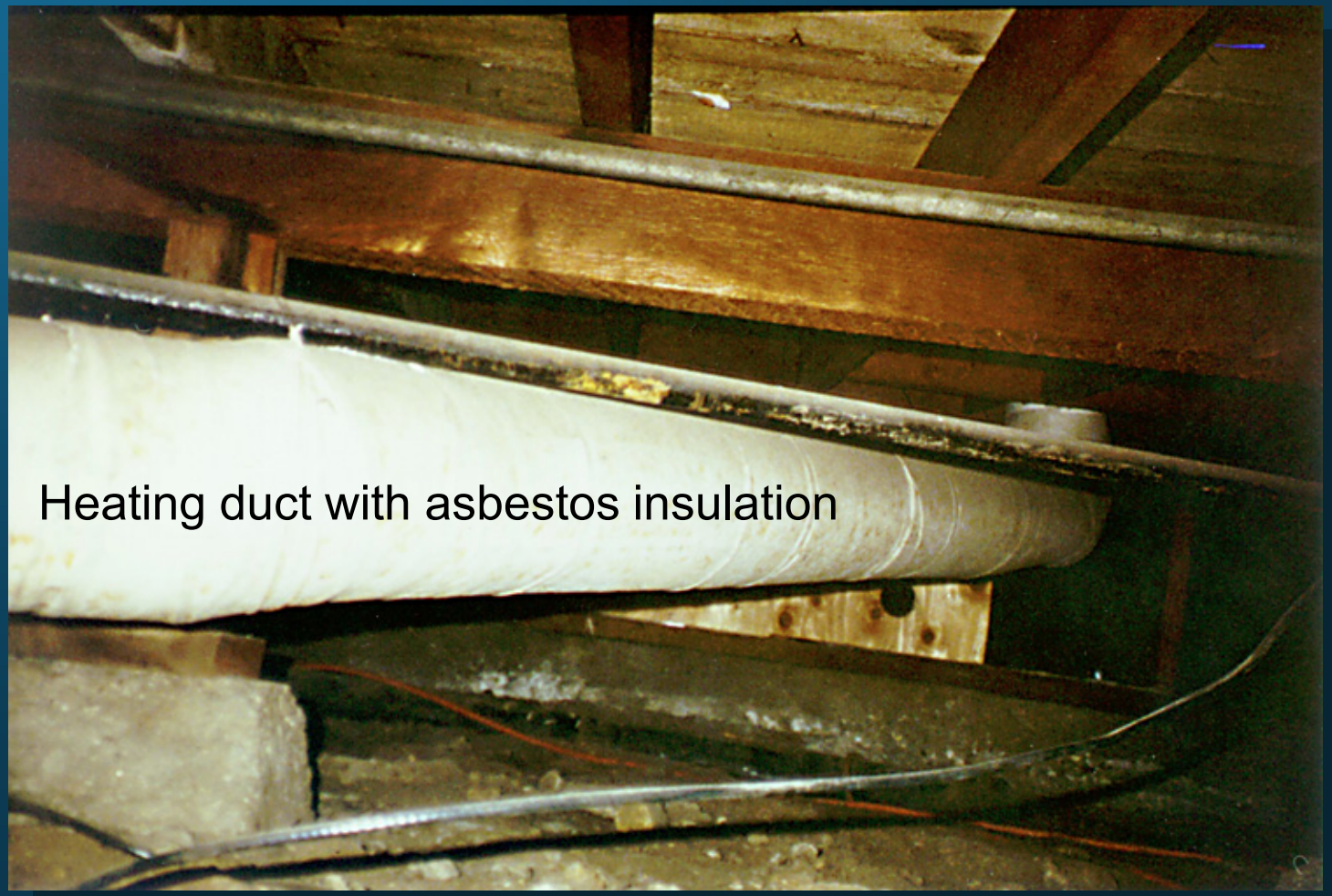
# Safety On The Job Site

- Crawl Spaces
- Demolition work
- Drilling wood / concrete
- Adhesive anchor use
- Hard hats
- Gloves

Use a respirator if needed—not a dust mask



# Do Not Disturb Asbestos



# Legal Perspectives

-Earthquake Basics

# Contractor Legally Responsible

- Damages resulting from negligence
- Basic contractor standard of care
  - applicable law
  - code provisions
  - regulations, industry standard of care
  - contract, plans, specifications

# Duty to Understand Earthquake Forces

- Base shear
- Earthquake overturning forces
- Lack of stability imposed
- Torsional rotation

# Contractor must understand methods to minimize earthquake failure

- Shear walls
- Brace frame methods
- Rigid frame methods

# Prescriptive vs. Engineered

- Check with local building dept. for prescriptive standards
- When in doubt, consult design professional

# Goal of Retrofit

- NOT an "earthquake proof home"
- IS for improved safety and performance of home during earthquake

# Pre-construction Meeting

- Useful tool
- May be required
- Purpose
  - review plans
  - ensure consistency of code interpretations
  - ensure adequacy and sufficiency of pla details

# Statute of Limitations

- 3-yr: construction defects following time tha owner knew that property was damaged
- 2-yr: errors in design
- 4-yr: breach of construction contract
- 10-yr: “latent”, undiscoverable defects

# Legal Perspectives

-Shear Walls

# Contractor Legally Responsible

- Keep up-to-date on engineering knowledge and construction practice
- Evolving standards of practice
- Building code often follows standard of practice

# Use Prescribed Dimensions

- Do not deviate without approval
  - Don't change length or location
  - Don't change nail size or spacing
- If can't be installed as specified, call design professional
- Document all changes and communications

# Coordination

- Contractor is responsible for coordination of trades
- Do not allow unpermitted plumbing or electric through shear walls

# Use Specified Materials

- Sheathing Material
- Fasteners
- Nails

# Quality Supervision

- Piecework compensation can result in poo quality work
- Quality supervision is important for contractor liability
- Nailing patterns is big source of liability for contractors

# Legal Perspectives

-Connections

# Contractor Legally Responsible

- No substitutions of lag screws for through bolts
- Beware of nonstandard framing
- Use proper anchor bolt assembly
- Protect workers from fumes

# Legal Perspectives

-Foundations

# Effective Communication When Observe Conditions Not in Scope of Work

- Water or plumbing leaks
- Drainage problems
- Termites or wood rot
- Split bottom framing members

# Pre-Job Walk Through

- Before bid on job
- If fail to communicate observed conditions, contractors risk liability
- Exclude conditions from contract or include as change order

# Legal Standards & Manufacturers' Specs

Standards of care can include manufacturers instructions

# Important

- Continuity of Foundation
- Shoring
- Concrete Quality

# Legal Perspectives

## Non-Structural Elements

# Contractor Should NOT take Responsibility for Recommending

- Carport cover bracing
- Water heater bracing
- Tank bracing
- Veneer selection
- Chimney bracing
- Other bracing

# Legal Issues

A Contractor's Legal Relationship with the Customer

# Basic Legal Concepts

- Communications
- Owner's concerns
- Contractor's liability
- Contract, plan, permits
- Tracking work

# Communications

- Communicate and Coordinate:
  - Customer
  - Subcontractors & workers
  - Building Department
  - Suppliers
  - Design professional
- Keep accurate records

# Owner's Concerns

- What they expect
  - Clear scope of work
  - Set limits on contractor's responsibilities
- Homeowner's primary concerns
  - Money
  - Disruption
  - Time

# Money

- Retrofitting for safety concerns or obligation
- Will get competitive bids
- Do NOT lowball…. unlikely to have money for change orders

# Disruptions

- Let customer know if & when expected
- Make arrangements with customer BEF
  disruptions occur

# Schedule

- State clearly projected timeline
- Make sure owner understands
- Let owner know IN ADVANCE of possible delays

# Background

- Provide references
- Proof of bonding and insurance
- Contractor's license number

# Limiting Contractor's Liability

- Why?
  - People ready to sue
  - Make sure of paperwork for protection
- How?
  - Liability Insurance

# Contracts……

## Why are contacts important?

- State what will be done
- How much will be paid for work
- Without it, difficult to be paid for work outside the scope of work

# Contracts…Key components

- Scope of Work
- Termination Options
- Exculpatory Provisions
- Liability Resolution
- Additional Work

# Contracts…Scope of Work

- Most important part of contract
- Refer to plans, specs, and codes
- Clearly state what is NOT in contract
- Exclusions ARE important

# Contracts...Termination Options

- State when and why contractor may terminate contract
  - Failure to pay progress payments
  - Undue interruption & interference
  - Similar circumstances

# Contracts…..

## Exculpatory Provisions

Relieves contractor from liability for existi
conditions on site that are not part of
scope of work

# Liability Revolution

- Expansion of construction defect claims agair contractors
  - Inadequate framing, plumbing & roof work
  - Poor soil work
  - Improper window installation
  - Waterproofing
- Include provision: No responsibility for existin conditions uncovered while performing work

# Contracts...Additional Work

- Retrofit often involves conditions of poor previous construction
- Make clear that owner responsible for wo due to unforeseen circumstances:
  - If increases scope of work
  - If owner request additional work
  - If necessitated by hidden existing conditions

# Contracts…Key Provisions

- Scope of work
- Time to complete project
- Price and payment schedule
- Subcontractor's names
- Change order provisions
- Termination provisions

# What Else?

- Have a good set of plans
- Have a building permit
- Keep track of the work in writing
- Get help when needed

# Warranties

- Do NOT guarantee an "earthquake proof" building
- Will protect occupants
- Should reduce seismic damage
- Building and contents may still be substantially damaged

# Warranties

- Typical: 1 year for workmanship
- By Law:
  - 10 yrs: latent defects
  - 4 yrs: patent defects
  - 3 yrs: negligence

# When Should Contractor Quit?

- Only if you have a right to do so
- Unresolvable disagreement